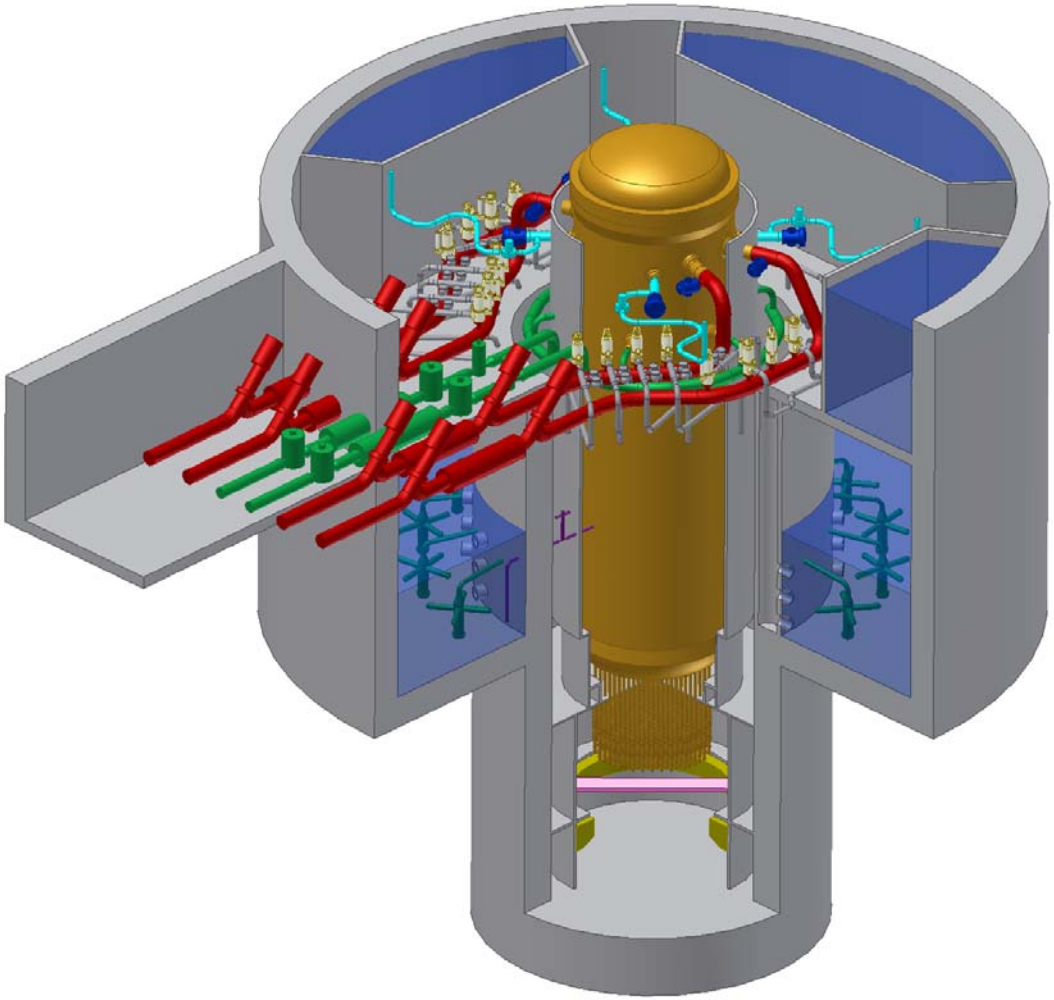
ESBWR Overview



J. Alan Beard

September 15, 2006

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Presentation Content

- BWR Design Evolution
- ESBWR Primary Characteristics
- ESBWR Passive Systems
- Differences from previous BWRs
- ESBWR Active Systems

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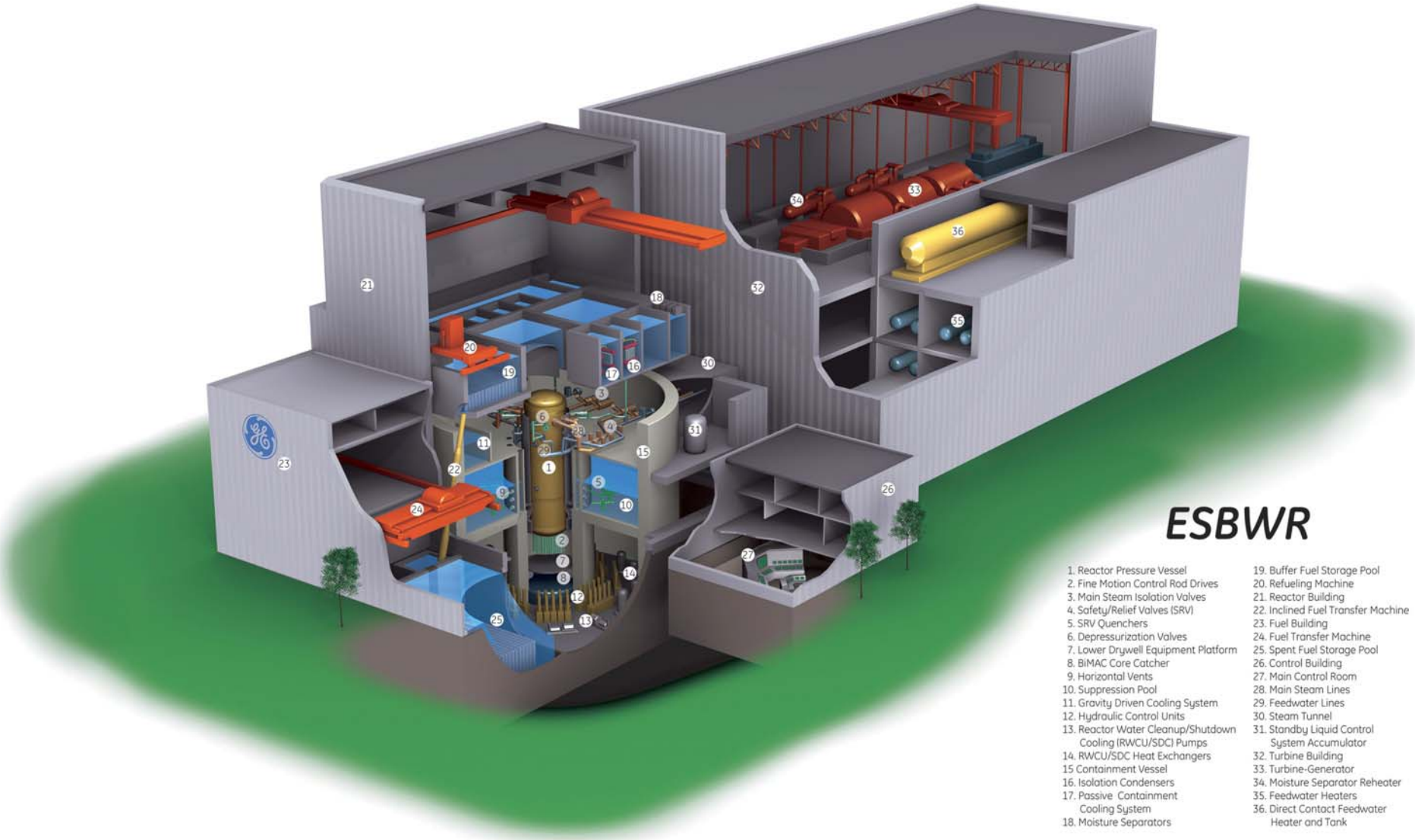

ESBWR

1. Reactor Pressure Vessel
2. Fine Motion Control Rod Drives
3. Main Steam Isolation Valves
4. Safety/Relief Valves (SRV)
5. SRV Quenchers
6. Depressurization Valves
7. Lower Drywell Equipment Platform
8. BiMAC Core Catcher
9. Horizontal Vents
10. Suppression Pool
11. Gravity Driven Cooling System
12. Hydraulic Control Units
13. Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) Pumps
14. RWCU/SDC Heat Exchangers
15. Containment Vessel
16. Isolation Condensers
17. Passive Containment Cooling System
18. Moisture Separators
19. Buffer Fuel Storage Pool
20. Refueling Machine
21. Reactor Building
22. Inclined Fuel Transfer Machine
23. Fuel Building
24. Fuel Transfer Machine
25. Spent Fuel Storage Pool
26. Control Building
27. Main Control Room
28. Main Steam Lines
29. Feedwater Lines
30. Steam Tunnel
31. Standby Liquid Control System Accumulator
32. Turbine Building
33. Turbine-Generator
34. Moisture Separator Reheater
35. Feedwater Heaters
36. Direct Contact Feedwater Heater and Tank

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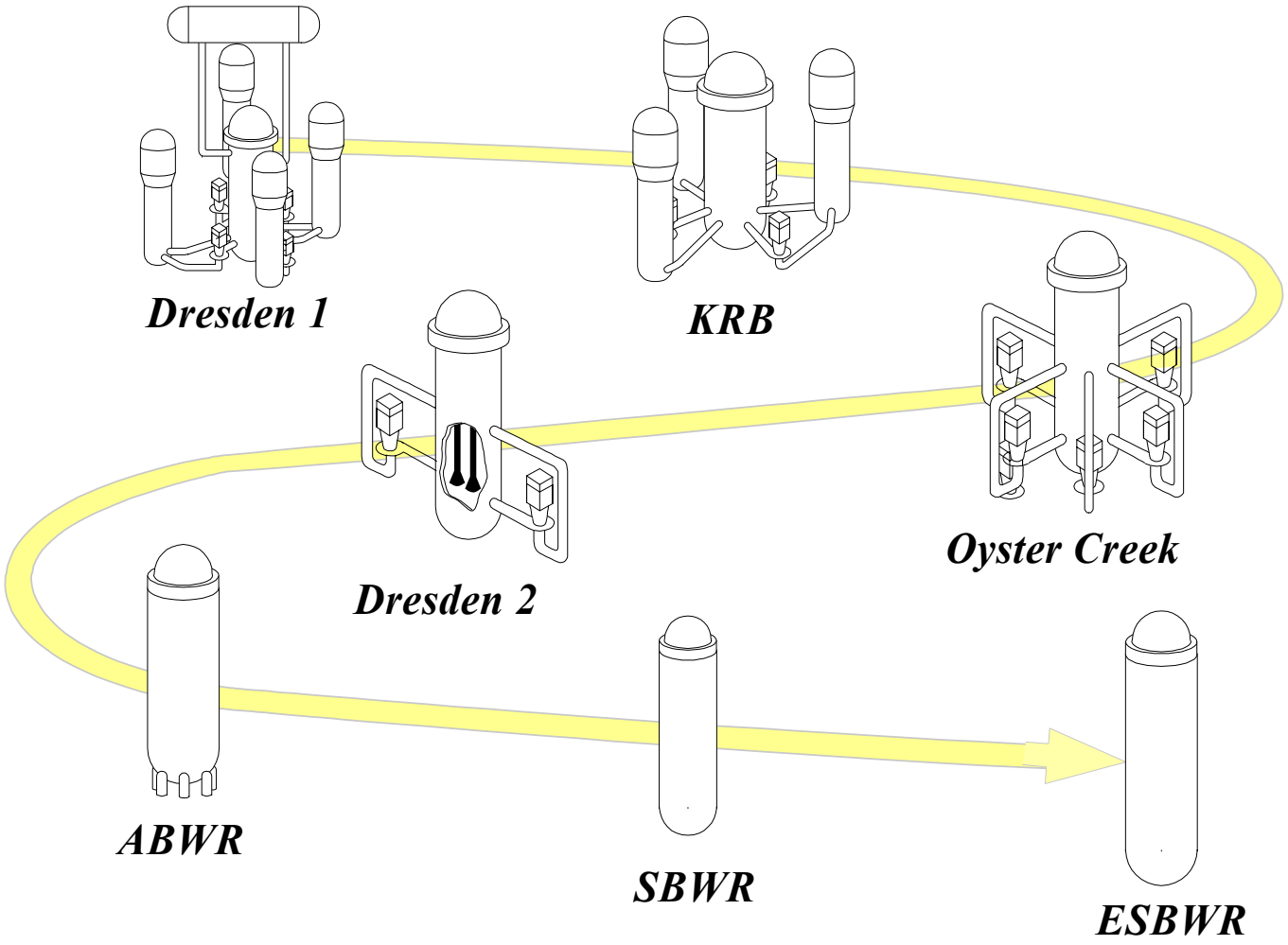
BWR Evolution



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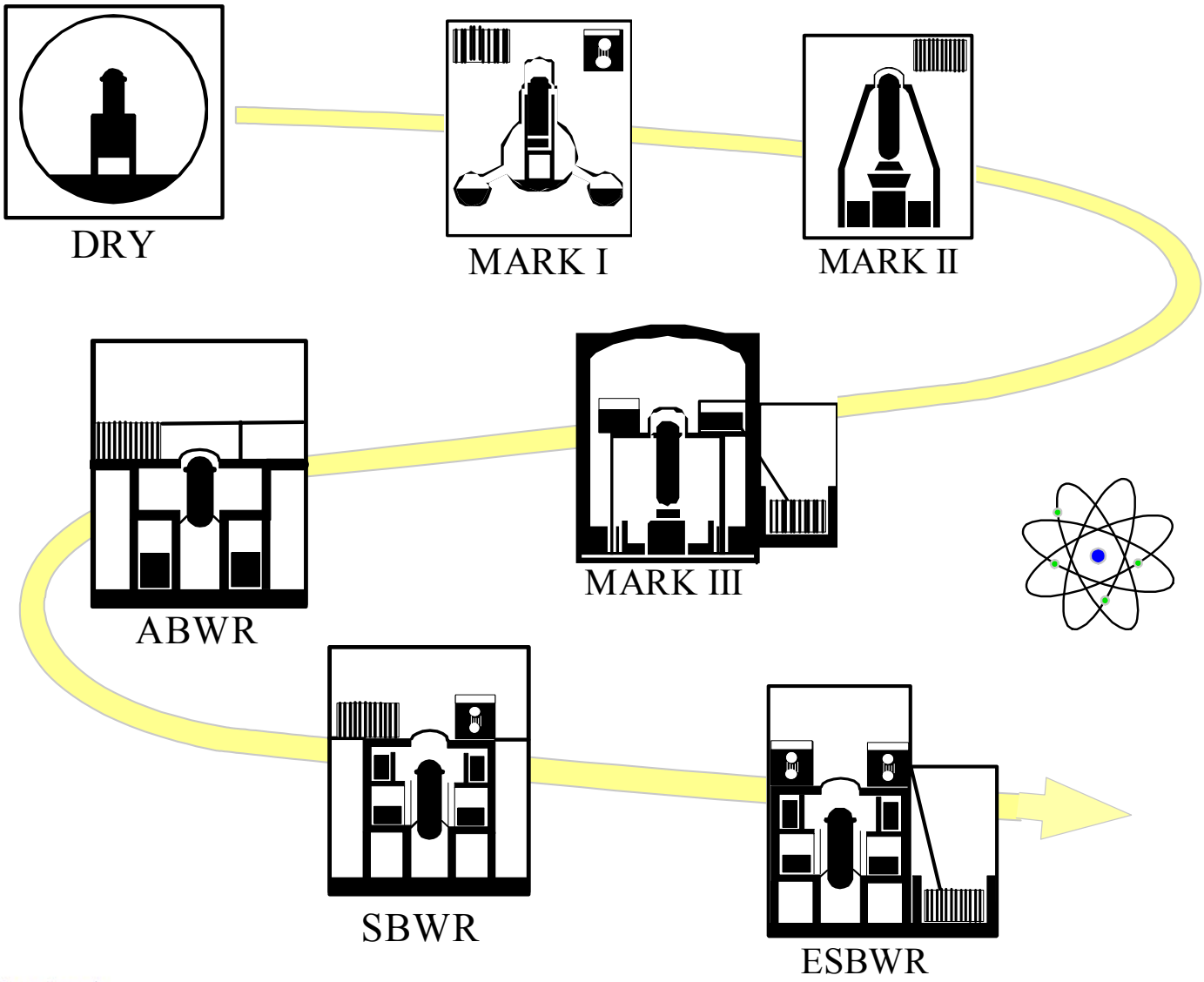
Containment Evolution



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Site Parameters

- EPRI Utility Requirements Document Plus
  - > Tornado
    - – 330 mph
  - > Extreme Winds
    - – 140 mph for safety-related
  - > Temperatures
    - – Bound the 3 ESP sites
  - > Seismic
    - – Reg Guide 1.60 plus a CEUS hard rock site

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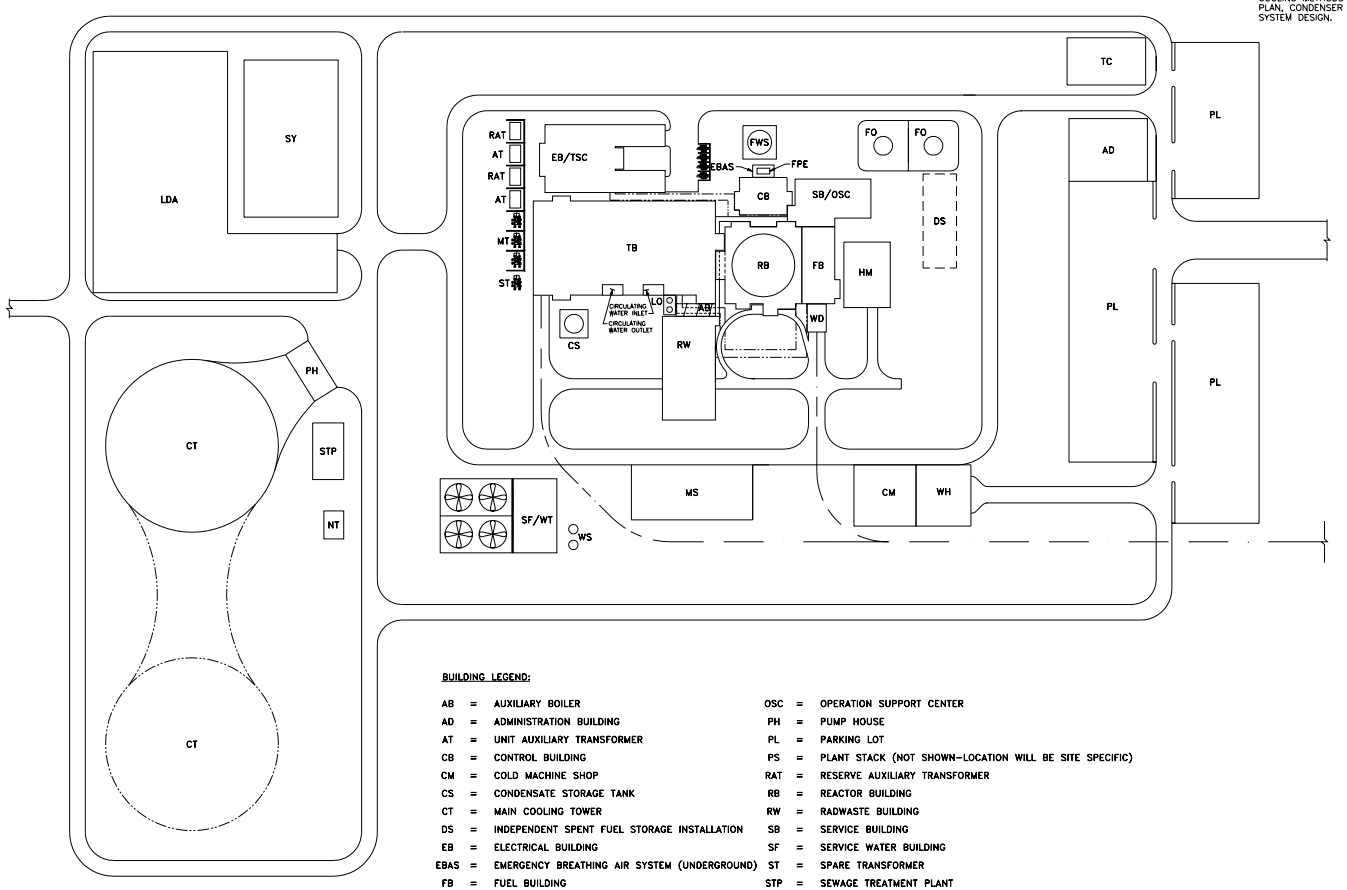
Site Plan

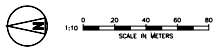
NOTES:

1. THIS PLOT PLAN REPRESENTS THE STANDARD ESBWR CONFIGURATION. THIS CONFIGURATION WILL BE MODIFIED FOR SITE SPECIFIC REQUIREMENTS DURING COMBINED OPERATING LICENSE APPLICATIONS.
2. THE REFERENCE NORMAL HEAT SINK IS SHOWN AS NATURAL DRAFT COOLING TOWERS; HOWEVER, SITE SPECIFIC AVAILABLE WET BULB AND COOLING WATER TEMPERATURES, ENVIRONMENTAL LIMITATIONS AND SPECIFIC TURBINE CONFIGURATION MAY DICTATE EITHER ONCE THROUGH OR MECHANICAL DRAFT TOWER COOLING. THESE SITE SPECIFIC ALTERNATE COOLING METHODS MAY ALSO CHANGE THE PLOT PLAN, CONDENSER AND CIRCULATING WATER SYSTEM DESIGN.



BUILDING LEGEND:

AB	=	AUXILIARY BOILER	OSC	=	OPERATION SUPPORT CENTER
AD	=	ADMINISTRATION BUILDING	PH	=	PUMP HOUSE
AT	=	UNIT AUXILIARY TRANSFORMER	PL	=	PARKING LOT
CB	=	CONTROL BUILDING	PS	=	PLANT STACK (NOT SHOWN–LOCATION WILL BE SITE SPECIFIC)
CM	=	COLD MACHINE SHOP	RAT	=	RESERVE AUXILIARY TRANSFORMER
CS	=	CONDENSATE STORAGE TANK	RB	=	REACTOR BUILDING
CT	=	MAIN COOLING TOWER	RW	=	RADWASTE BUILDING
DS	=	INDEPENDENT SPENT FUEL STORAGE INSTALLATION	SB	=	SERVICE BUILDING
EB	=	ELECTRICAL BUILDING	SF	=	SERVICE WATER BUILDING
EBAS	=	EMERGENCY BREATHING AIR SYSTEM (UNDERGROUND)	ST	=	SPARE TRANSFORMER
FB	=	FUEL BUILDING	STP	=	SEWAGE TREATMENT PLANT
FO	=	DIESEL FUEL OIL STORAGE TANK	SY	=	SWITCH YARD
FPE	=	FIRE PUMP ENCLOSURE	TB	=	TURBINE BUILDING
FWS	=	FIRE WATER STORAGE TANK	TC	=	TRAINING CENTER
HM	=	HOT MACHINE SHOP & STORAGE	TSC	=	TECHNICAL SUPPORT CENTER
LDA	=	LAY DOWN AREA	WD	=	WASH DOWN BAYS (EQUIPMENT ENTRY)
LO	=	DIRTY/CLEAN LUBE OIL STORAGE TANK	WH	=	WAREHOUSE
MS	=	MISCELLANEOUS SERVICE AREA	WS	=	WATER STORAGE
MT	=	MAIN TRANSFORMER	WT	=	WATER TREATMENT
NT	=	NITROGEN STORAGE TANK			



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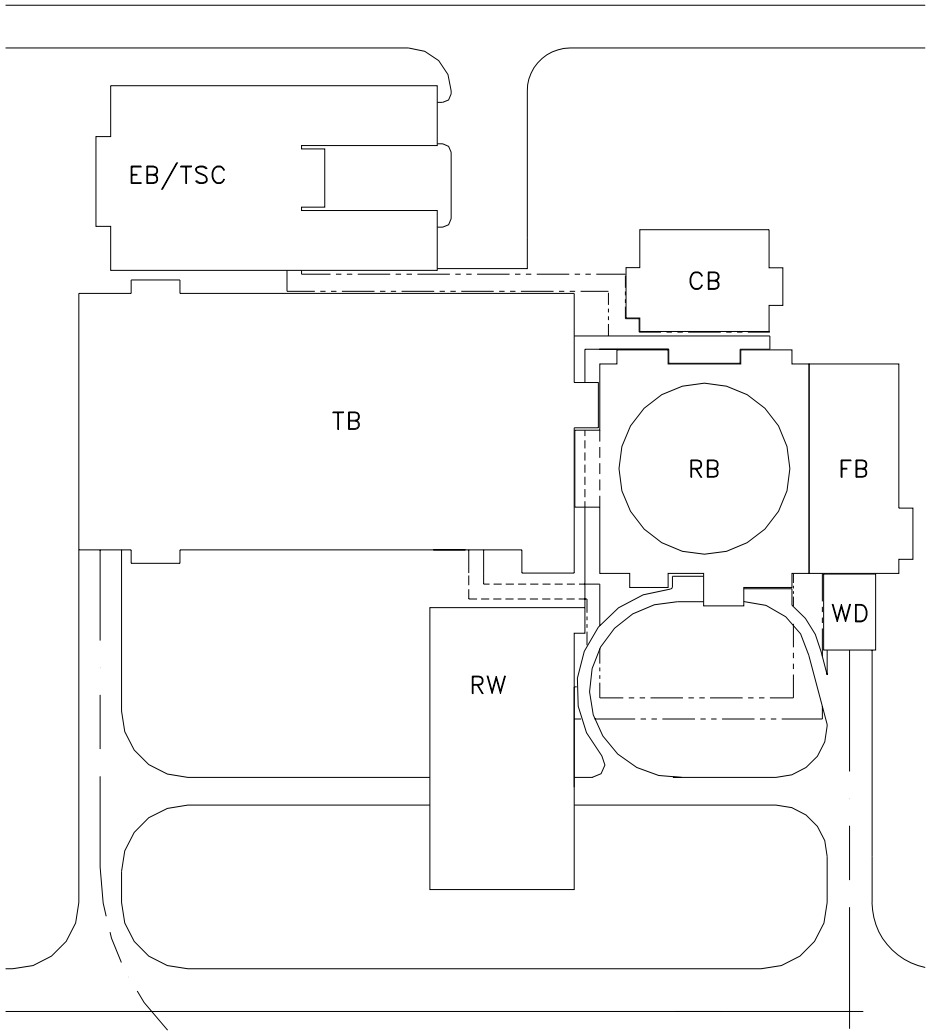
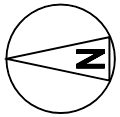
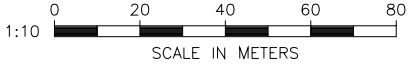
Power Block Arrangement







ESBWR Basic Parameters

- 4,500 Megawatt Core Thermal Power
- ~1, 575 to 1,600 Megawatt Electric Gross
  - > Nominal Summer Rating
- Natural Circulation
  - > No recirculation pumps
- Passive Safety Systems
  - > 72 hours passive capability

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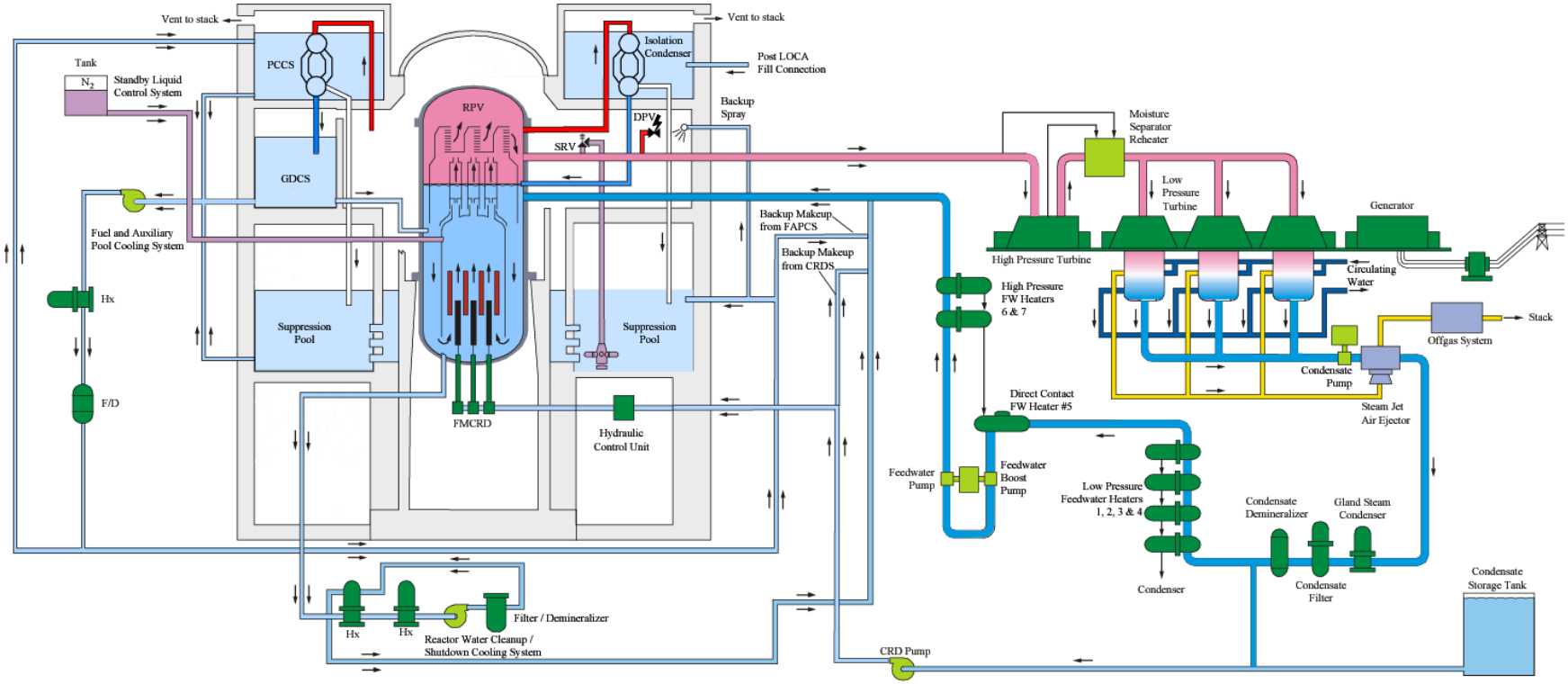

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What's different about ESBWR

ABWR	ESBWR
Recirculation System + support systems	Eliminated
HPCF System (2 each)	Eliminated need for ECCS pumps
LPFL (3 each)	Utilize passive and stored energy
Residual Heat Removal (3 each)	Non-safety, combined with cleanup system
Safety Grade Diesel Generators (3 each)	Eliminated – only 2 non-safety grade diesels
RCIC	Replaced with IC heat exchangers
SLC –2 pumps	Replaced pumps with accumulators
Reactor Building Service Water (Safety Grade) And Plant Service Water (Safety Grade)	Made non-safety grade

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Optimized Parameters for ESBWR

Parameter	BWR/4-Mk I(Browns Ferry 3)	BWR/6-Mk III (Grand Gulf)	ABWR	ESBWR
Power (MWt/MWe)	3293/1098	3900/1360	3926/1350	4500/1590
Vessel height/dia. (m)	21.9/6.4	21.8/6.4	21.1/7.1	27.7/7.1
Fuel Bundles (number)	764	800	872	1132
Active Fuel Height (m)	3.7	3.7	3.7	3.0
Power density (kw/l)	50	54.2	51	54
Recirculation pumps	2(large)	2(large)	10	zero
Number of CRDs/type	185/LP	193/LP	205/FM	269/FM
Safety system pumps	9	9	18	zero
Safety diesel generator	2	3	3	zero
Core damage freq./yr	1E-5	1E-6	1E-7	3E-8
Safety Bldg Vol (m^3/MWe)	115	150	160	< 130

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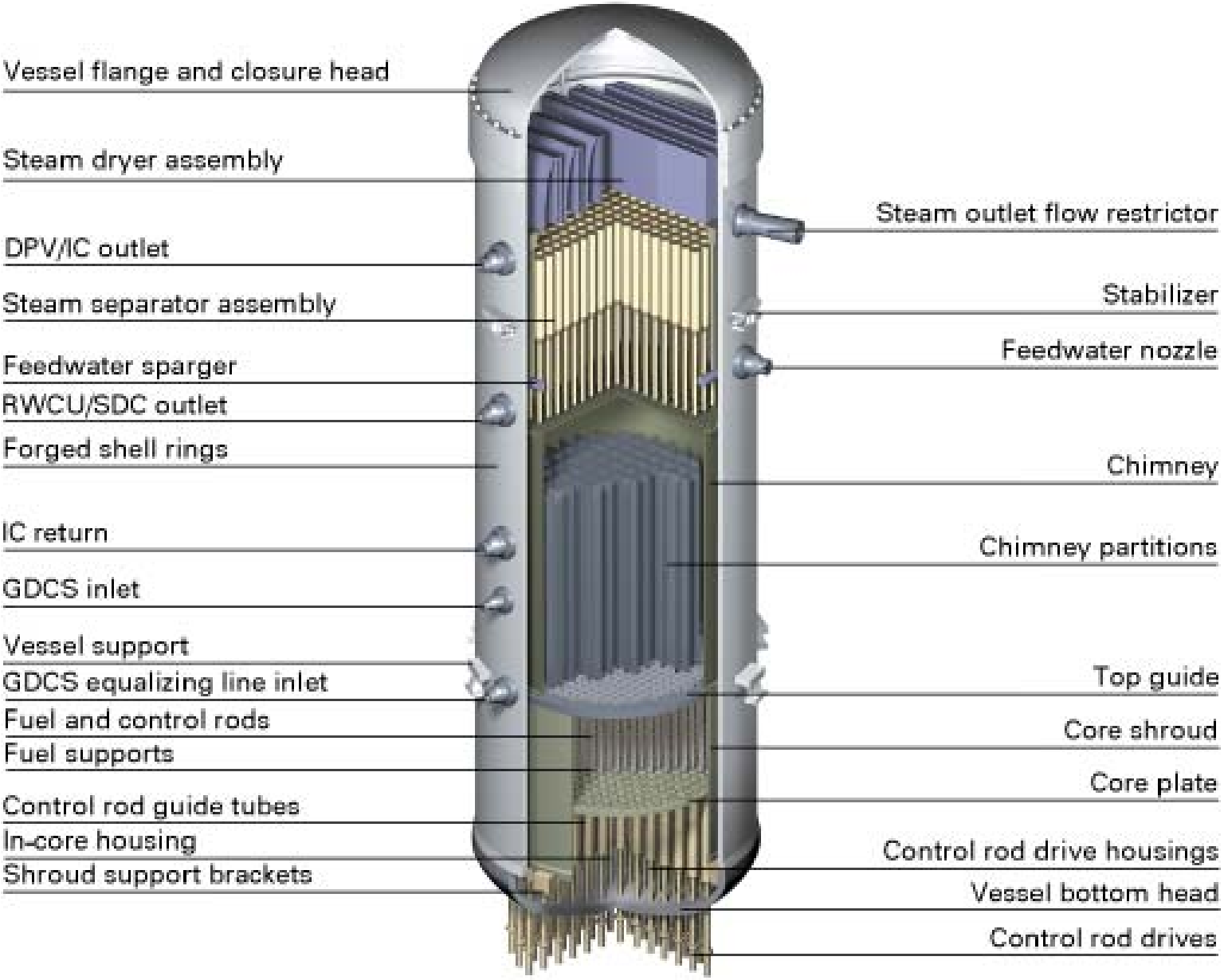

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Other Design Improvements

- 100% Steam Bypass
  - > Island Mode of Operation
- Fine Motion Control Rod Drives (FMCRD)
- Shoot-out Steel Eliminated
- Integrated Head Vent Pipe
- Improved Incore Instrumentation
  - > Start-up Range Neutron Monitor (SRNM)
  - > Gamma Thermometer
    - – No Traversing Incore Probe (TIP)

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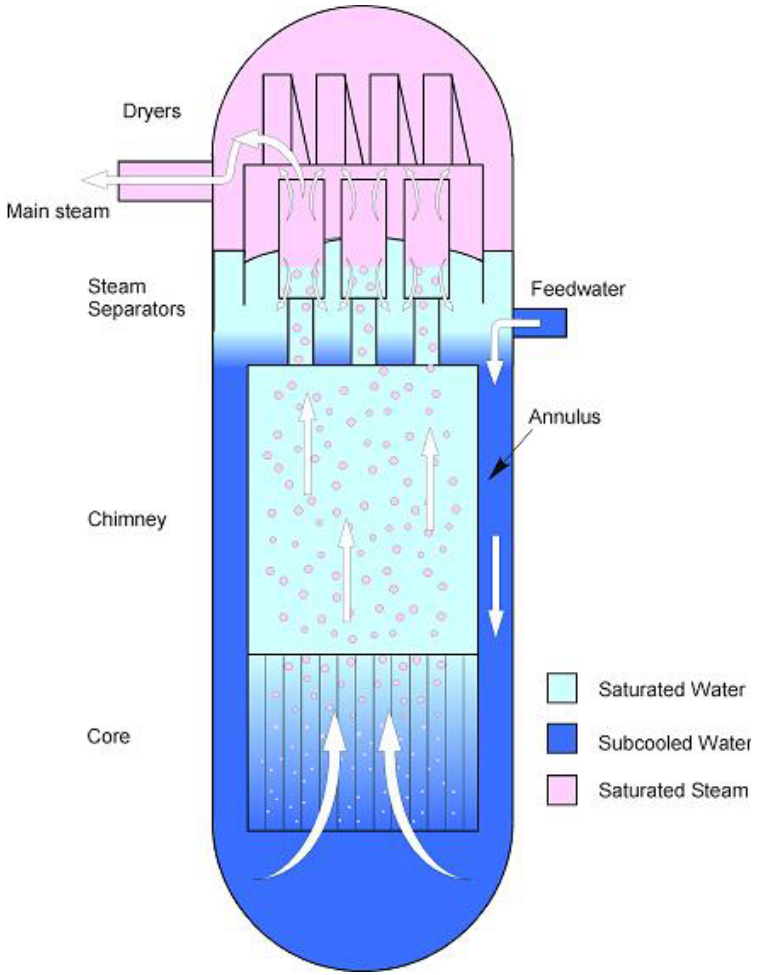
Natural Circulation

Simplification without performance loss ..

- **Passive safety/natural circulation**
  - Increase the volume of water in the vessel
  - Increase driving head
- **Significant reduction in components**
  - Pumps, motors, controls, HXers
- **Power Changes with Control Rod Drives**
  - Minimal impact on maintenance



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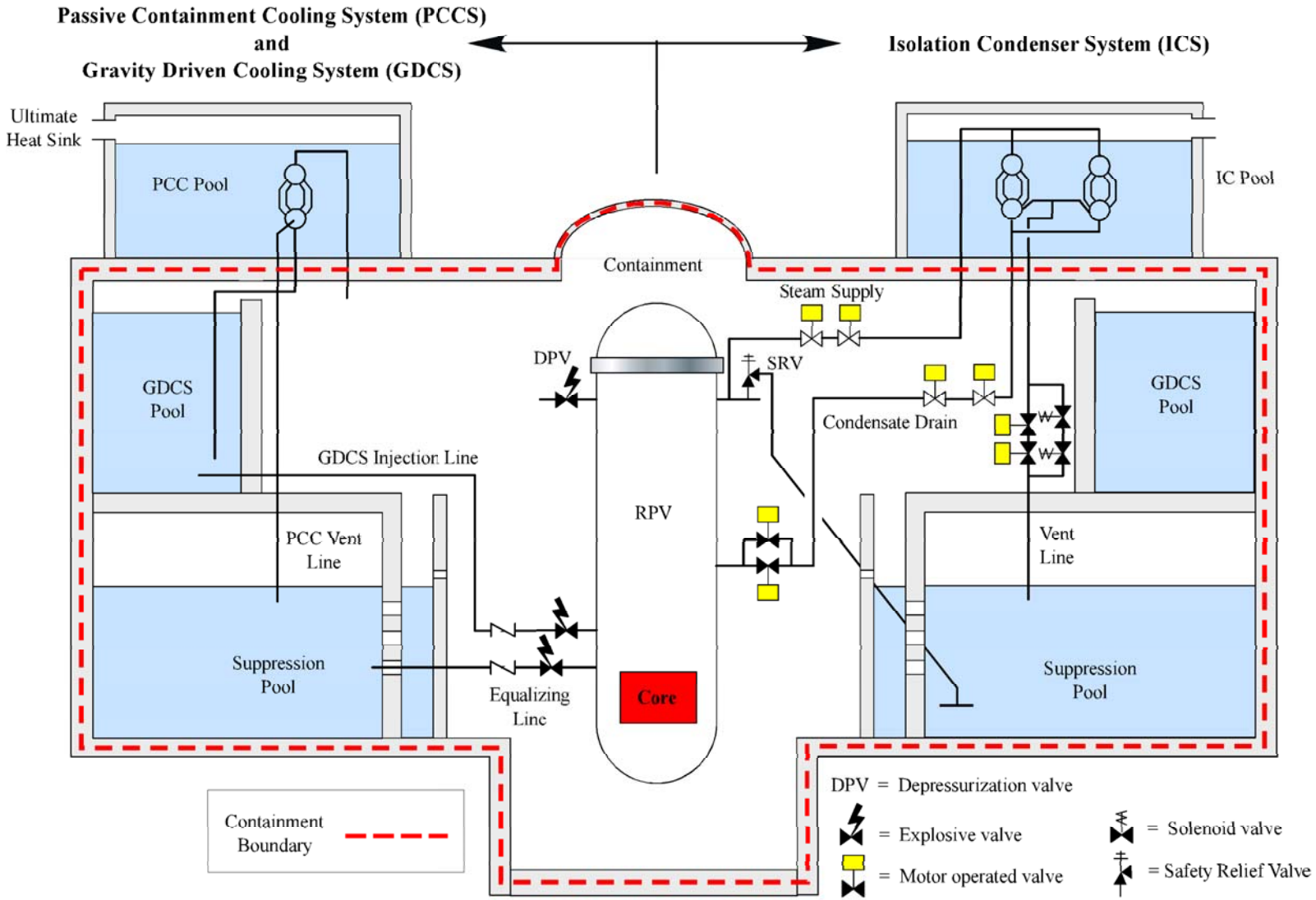
Passive Safety



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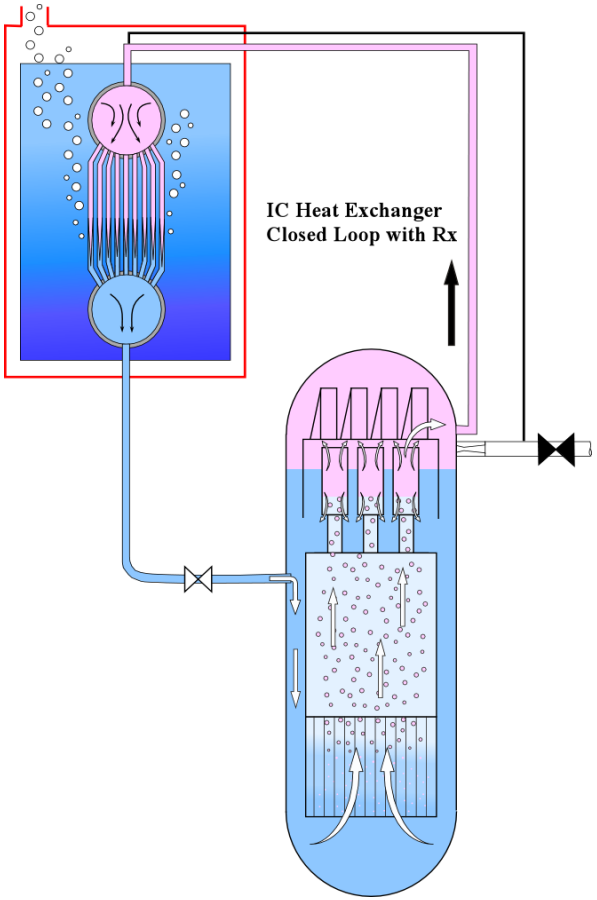
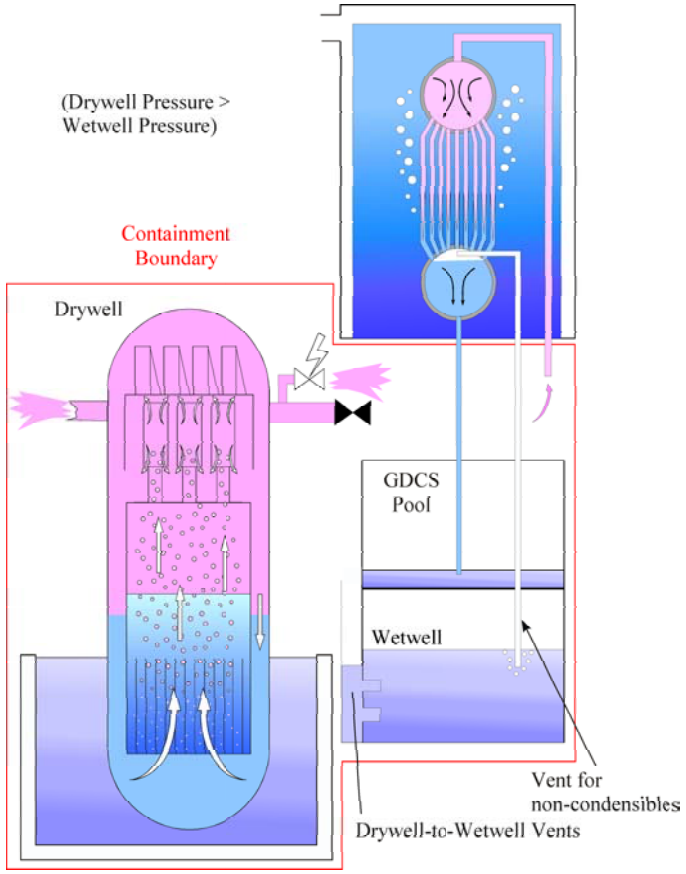
Passive Safety Systems …

Isolation Condenser System



Passive Containment Cooling



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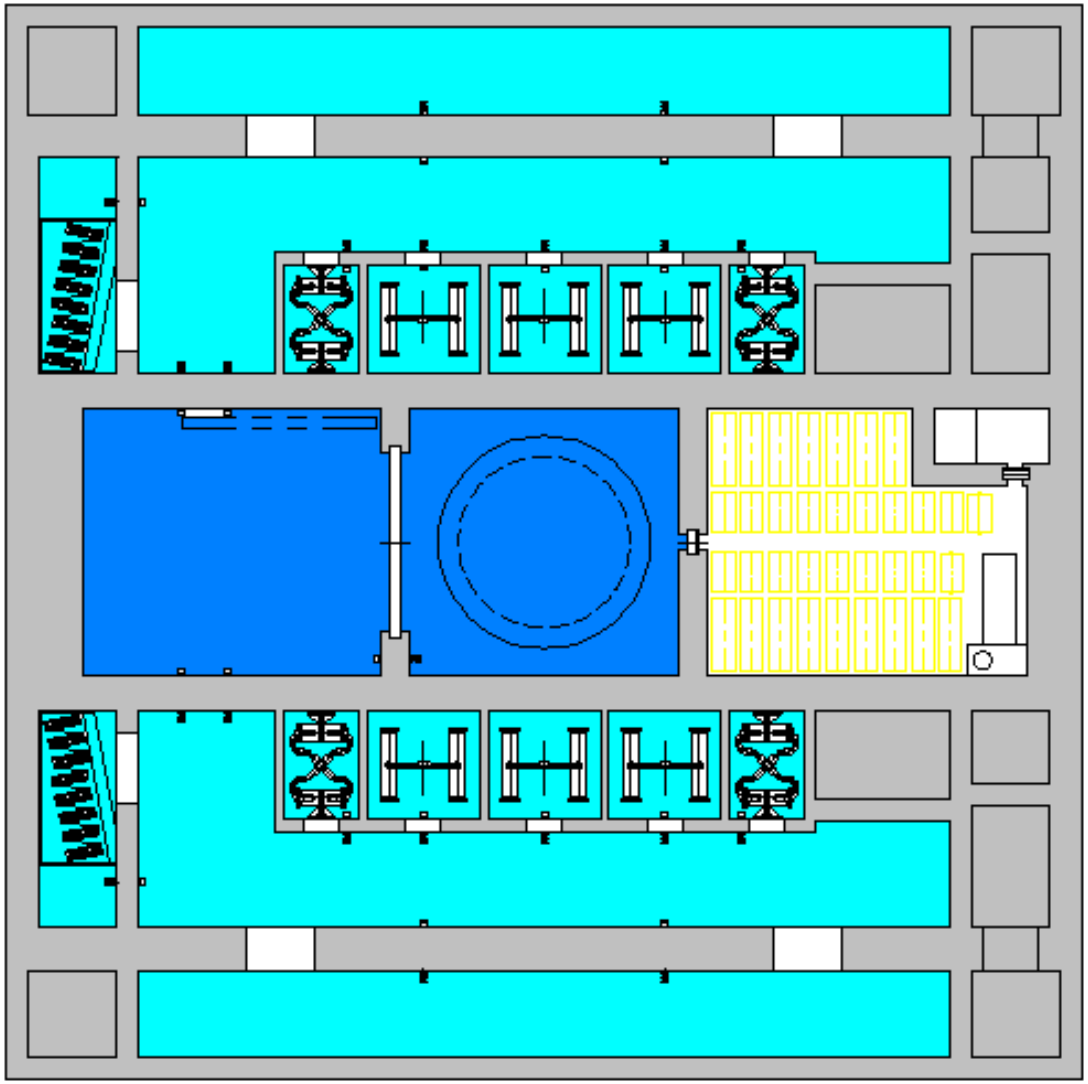
72 Hours Passive Capability



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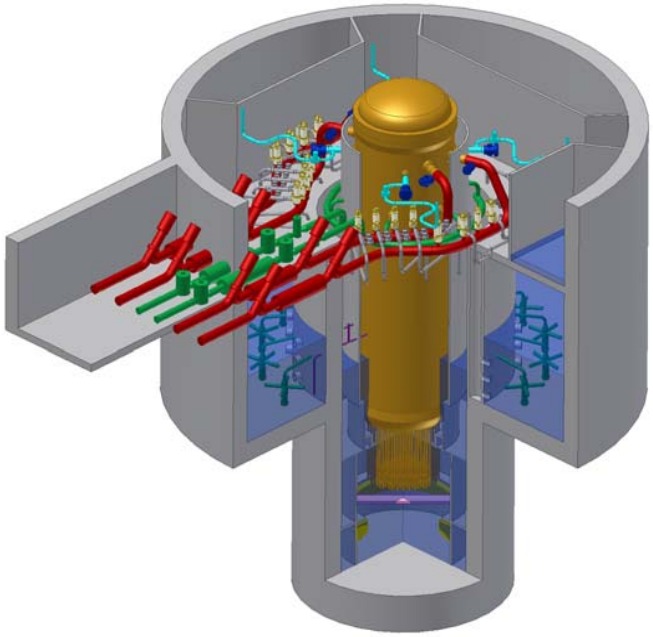
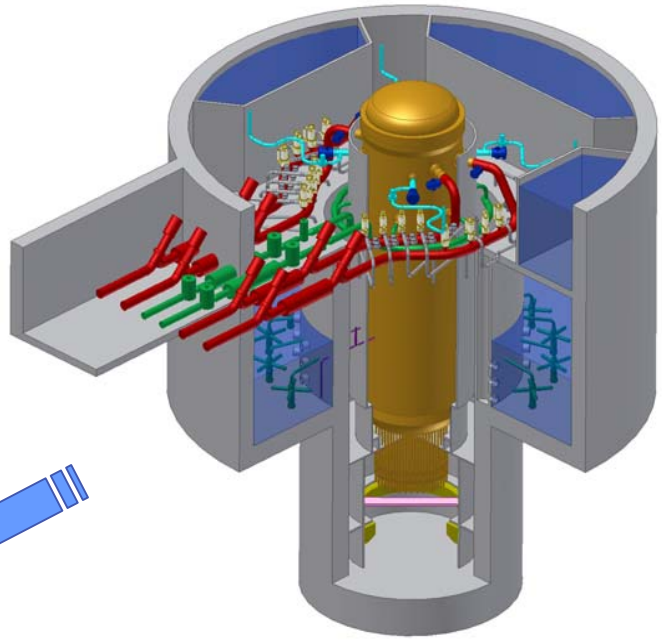
Gravity Driven Cooling System …

Simple design
Simple analyses

Extensive testing
Large safety margins





Gravity driven flow keeps core covered

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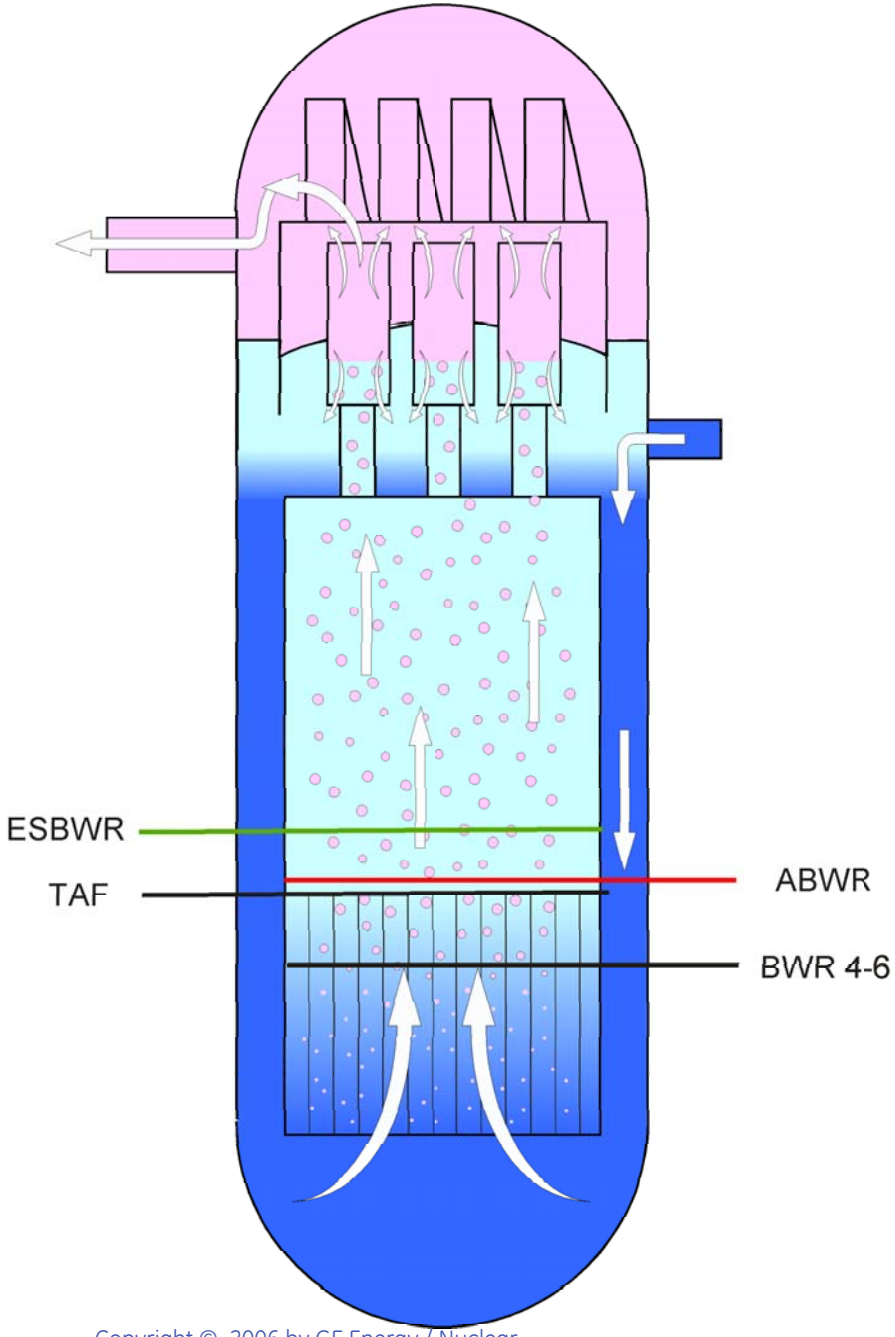
LOCA Water Level Response



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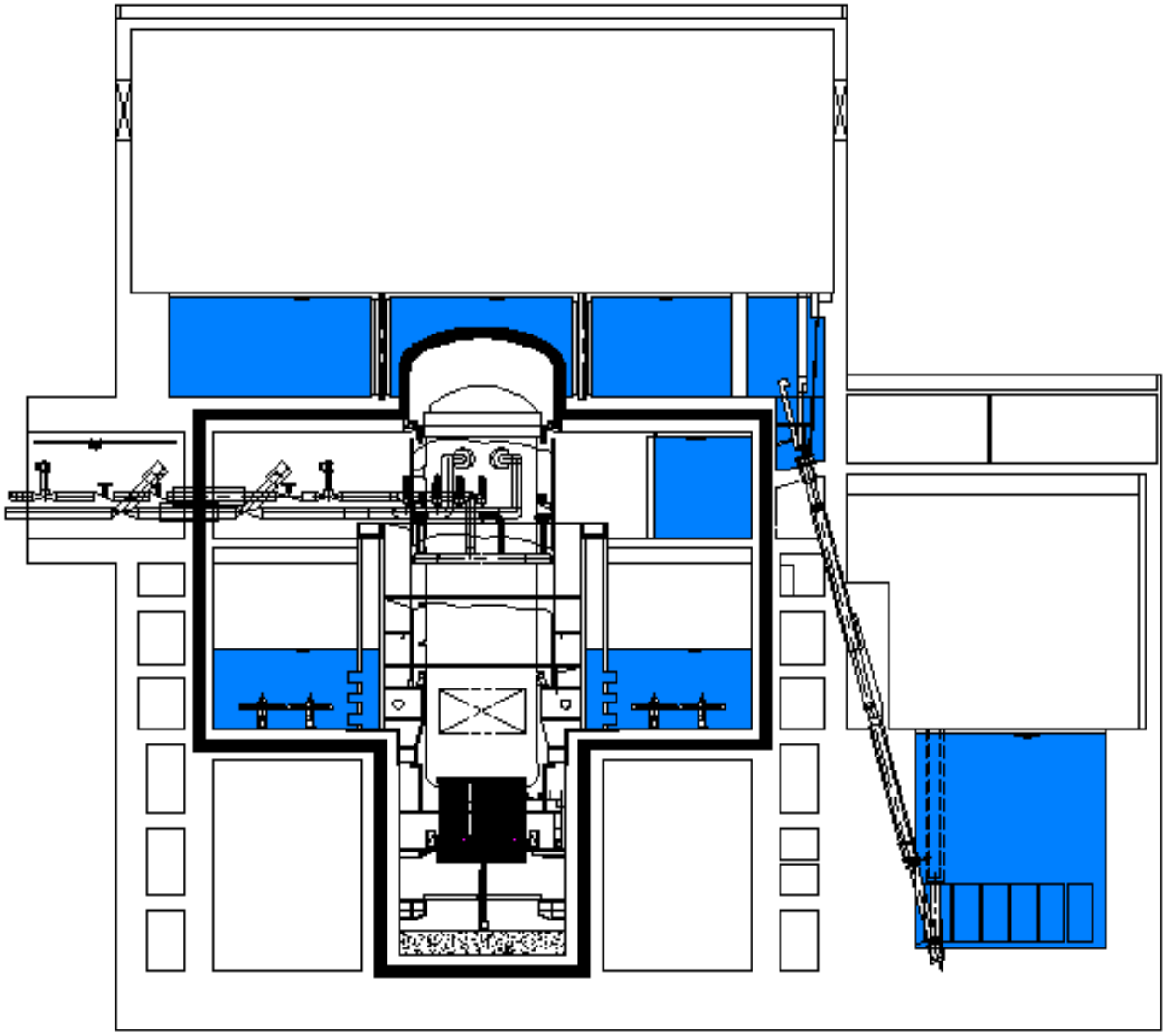
Reactor and Fuel Building



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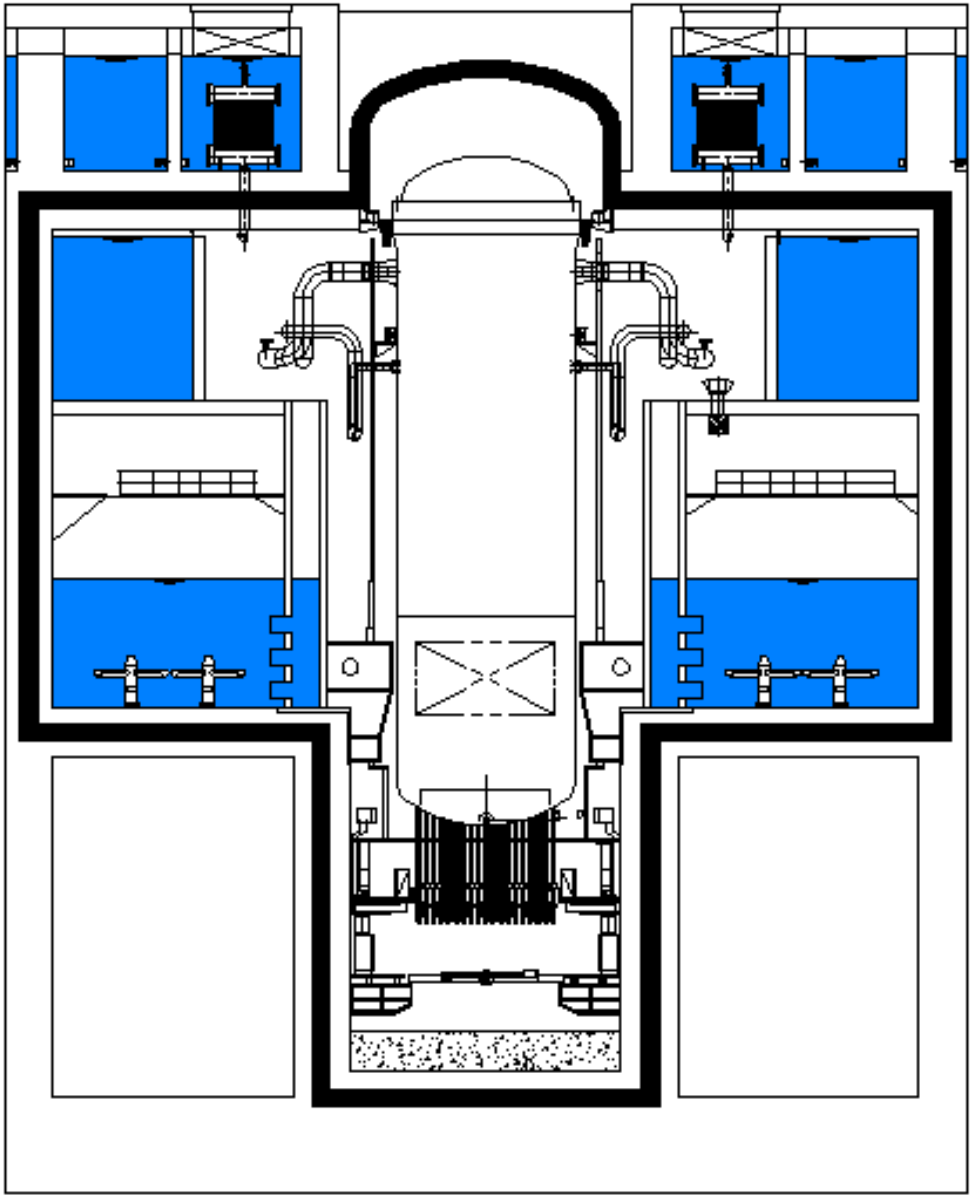
Containment



Isolation Condensers

- ICs provide passive decay heat removal
  - > Single Failure Criteria apply
  - > No lift of the Safety Relief Valves (SRVs)
  - > Operates in all Design Basis Conditions except medium and large break LOCAs
  - > ICs transport decay heat direct from NSSS to the Ultimate Heat Sink
    - > No steaming in the primary containment
  - > Rapidly reduces RPV pressure
  - > Redundant Active Components

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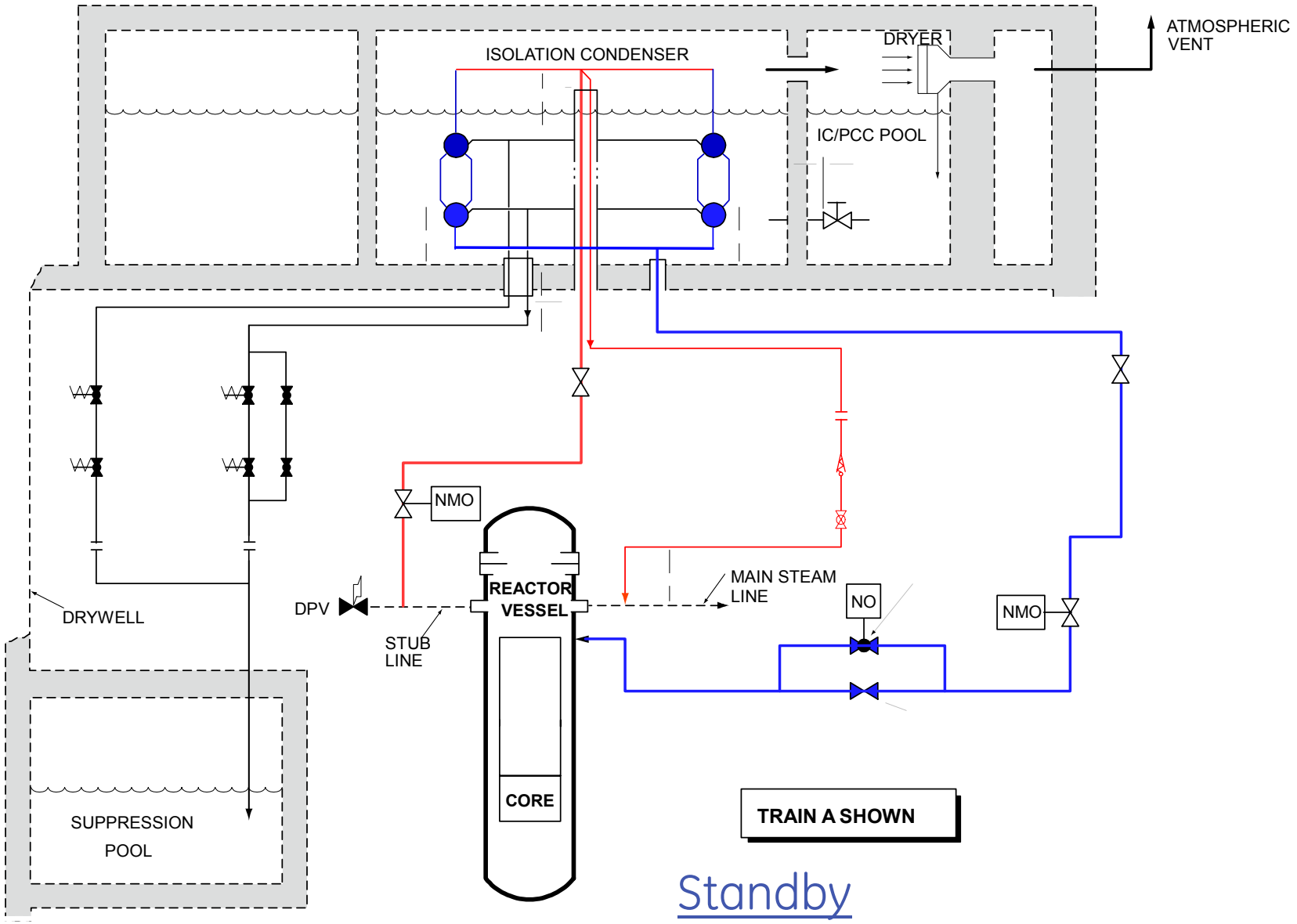

Standby

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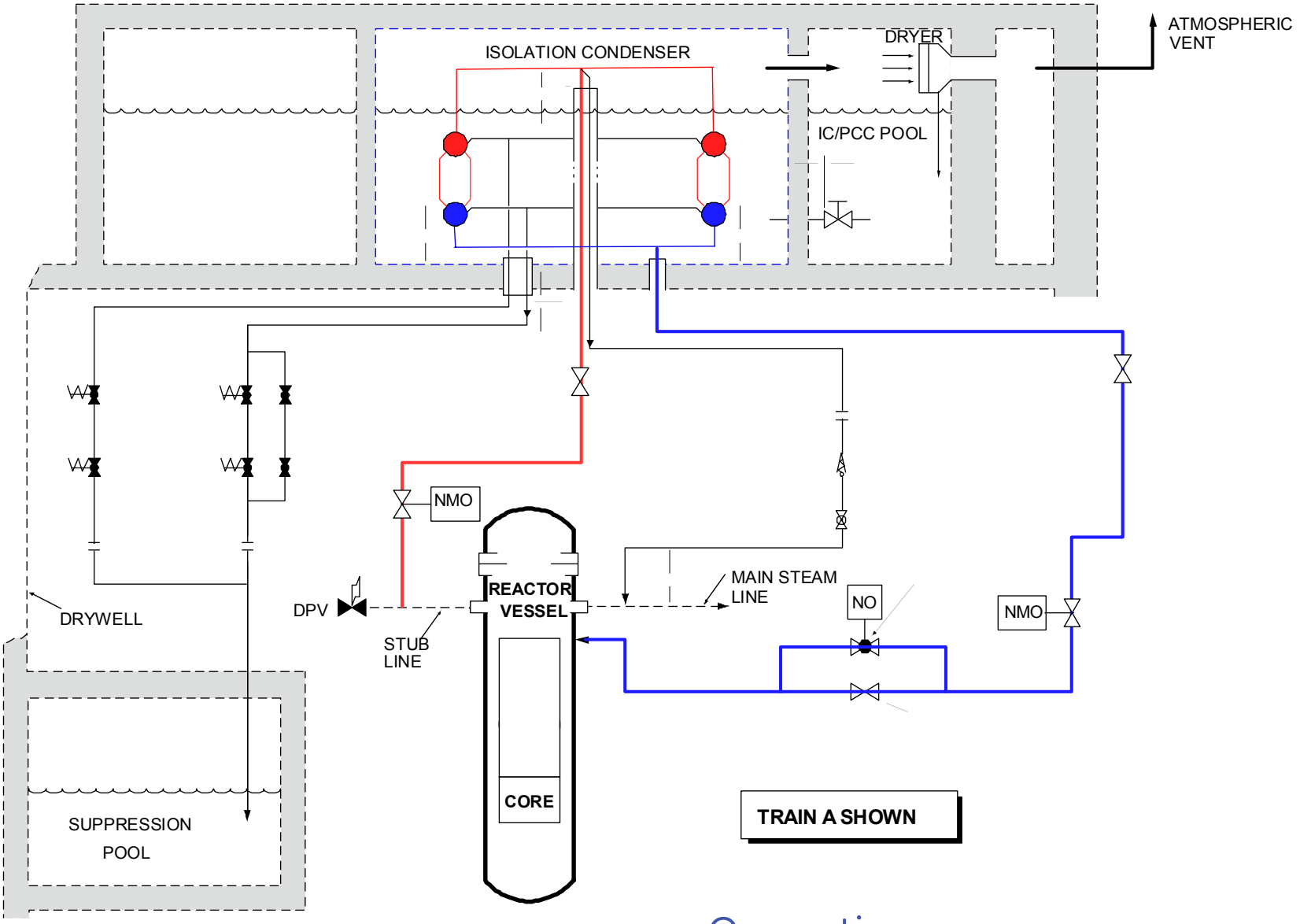

Operation

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Passive Containment Cooling

- PCCs provide passive decay heat removal from the primary containment
  - > Operates in medium and large break LOCAs
  - > Provides backup of ICs if needed
    - – RPV is depressurized using DPVs
  - > Entirely Passive
    - > ~40 hours with demineralized water
  - > PCCs transport decay heat direct from Primary Containment to the Ultimate Heat Sink

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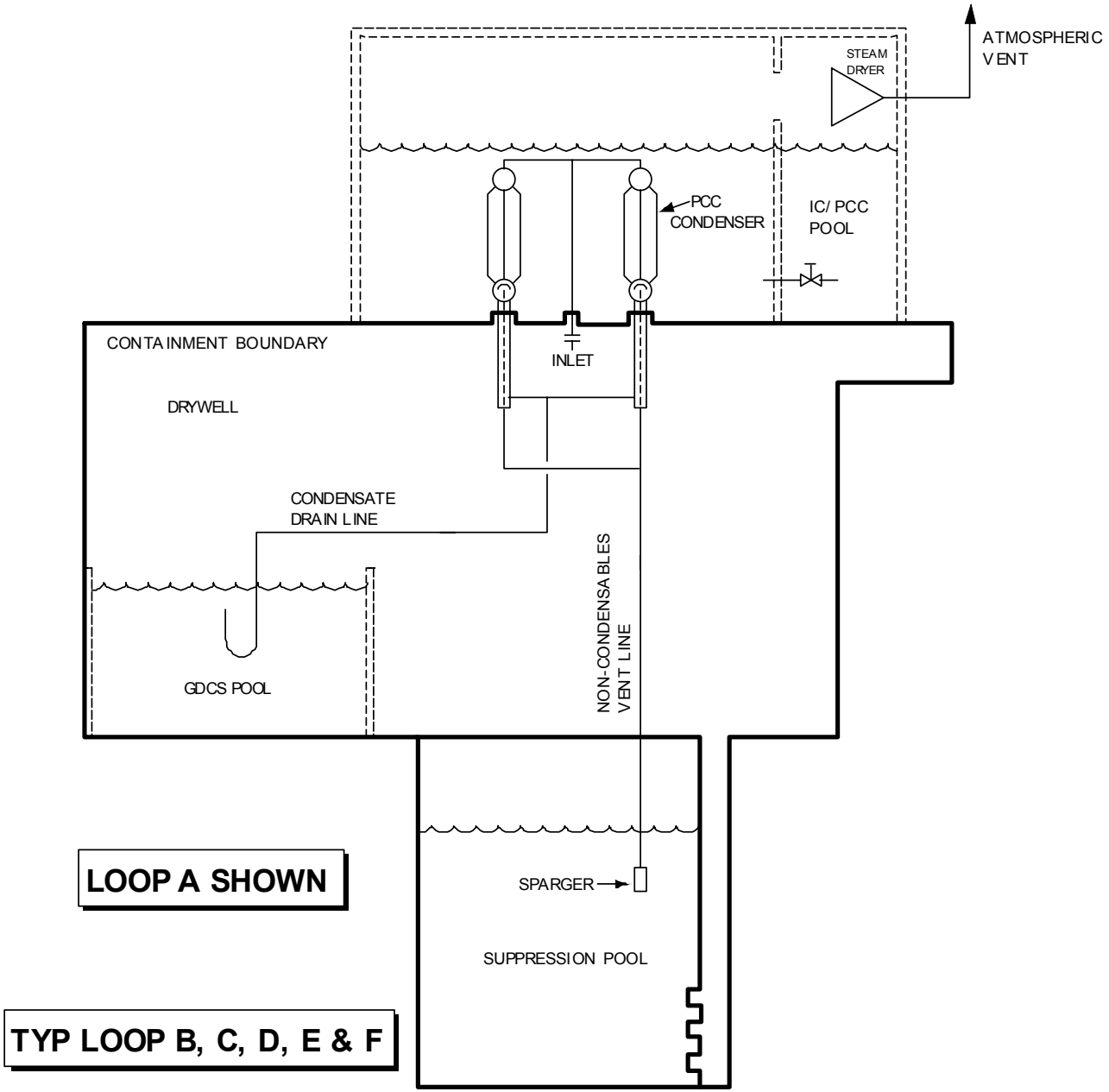

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Emergency Core Cooling (ECC)

- Gravity Driven Cooling System (GDCS)
  - Three Pools
  - Four Trains
- Automatic Depressurization System (ADS)
  - 10 of 18 Safety Relief Valves (SRV)
    - Pneumatic actuation
  - 8 Depressurization Valves (DPV)
    - Squib actuated

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Emergency Core Cooling (cont)

- Core remains covered for entire range of Design Basis Accidents
  - > No fuel heat-up
- Complies with 10 CFR 50.46
  - > Codes have been approved by NRC
- Stored water is sufficient to flood containment and RPV to above the top of fuel
  - > 1 meter above TAF

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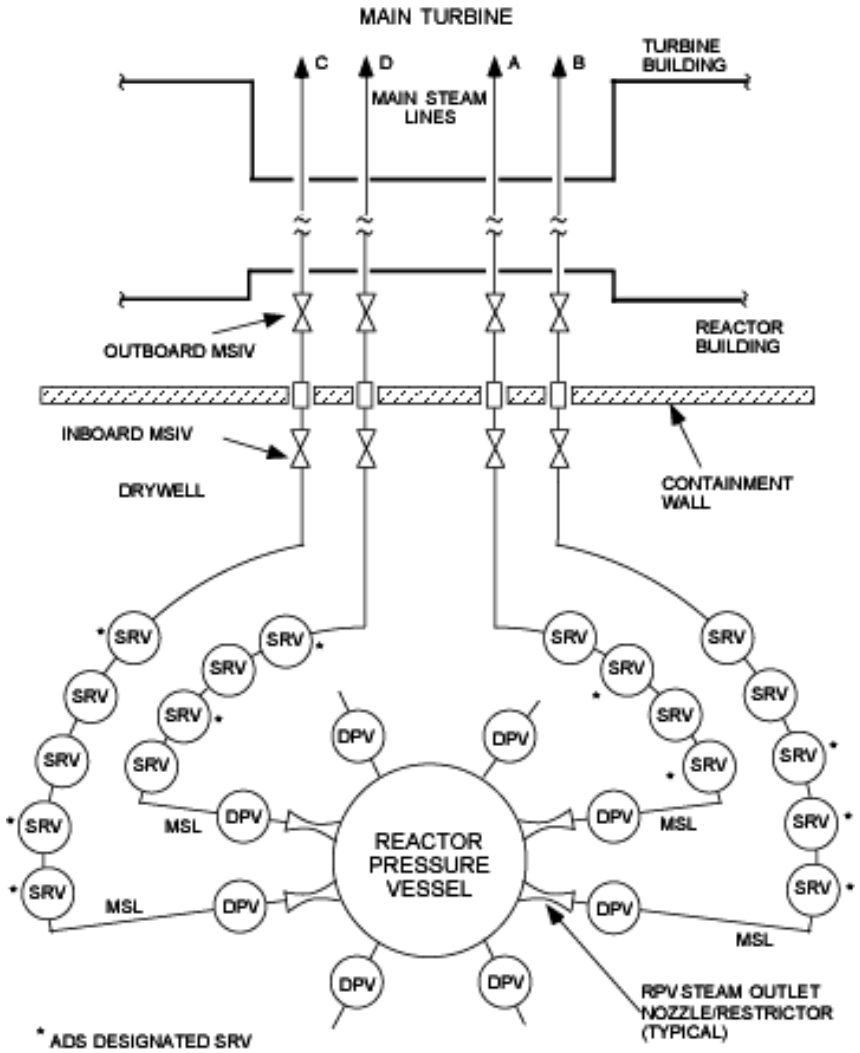
MSIV, SRV and DPV Arrangement



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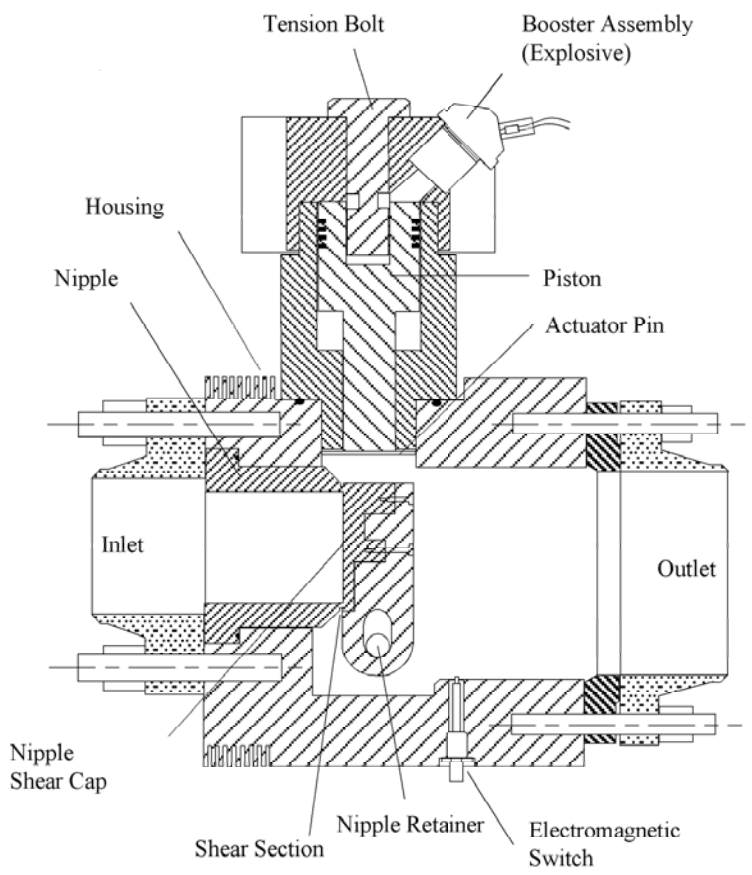
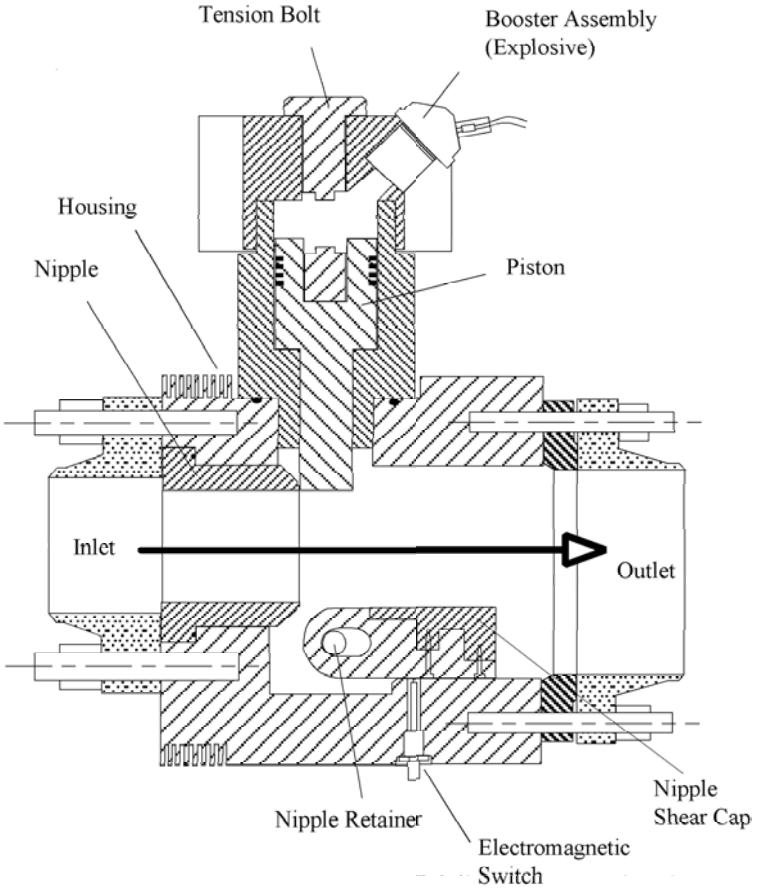
Depressurization Valve (DPV)



Unfired - Closed



Fired - Open

Depressurization Valve
Cross Section

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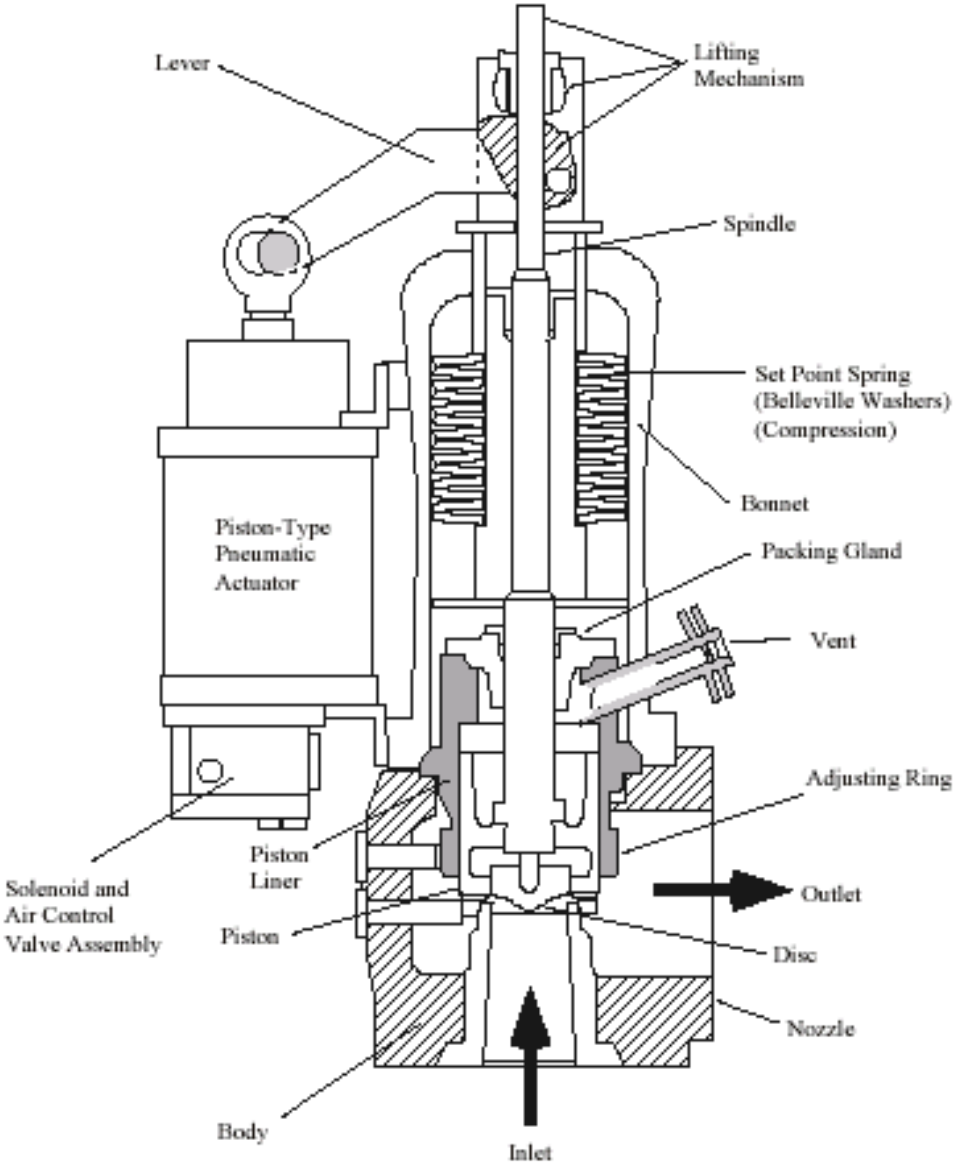

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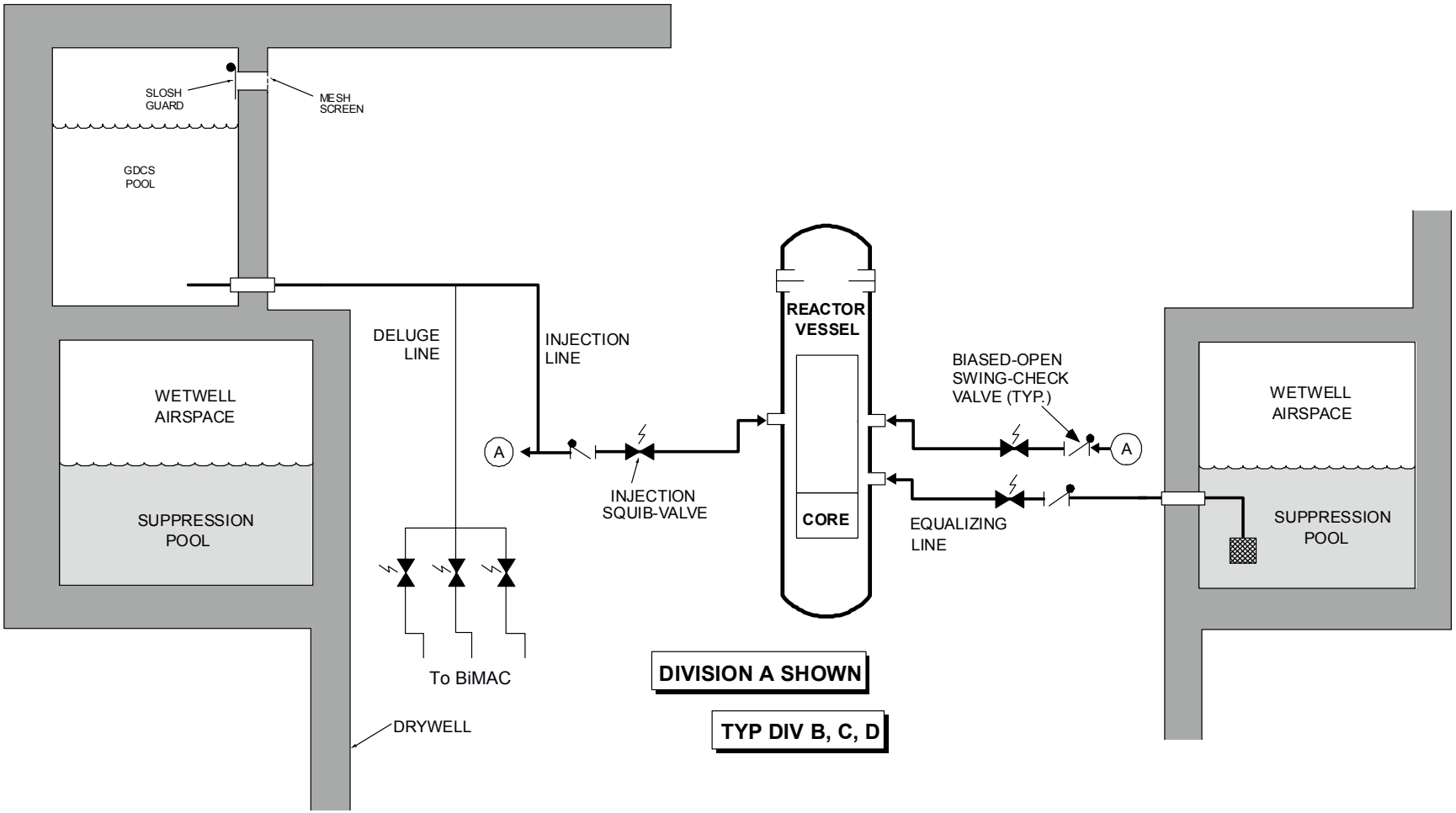

Gravity-Driven Cooling System

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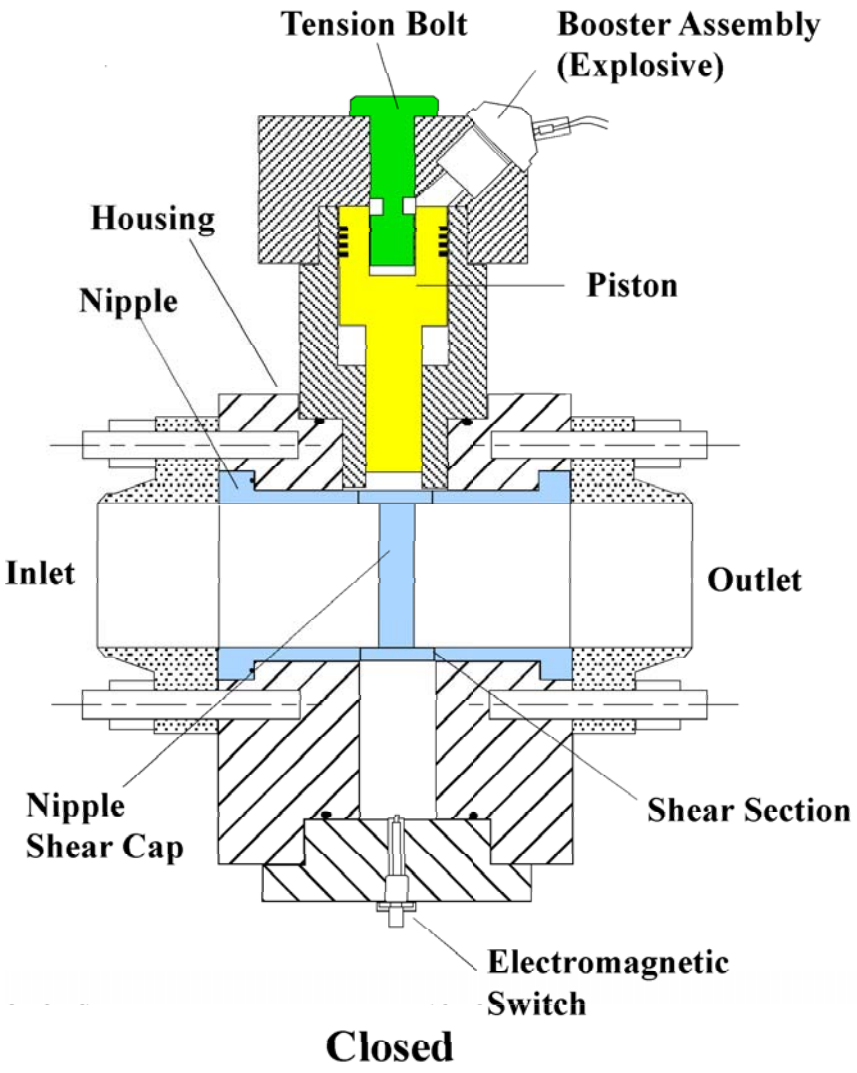

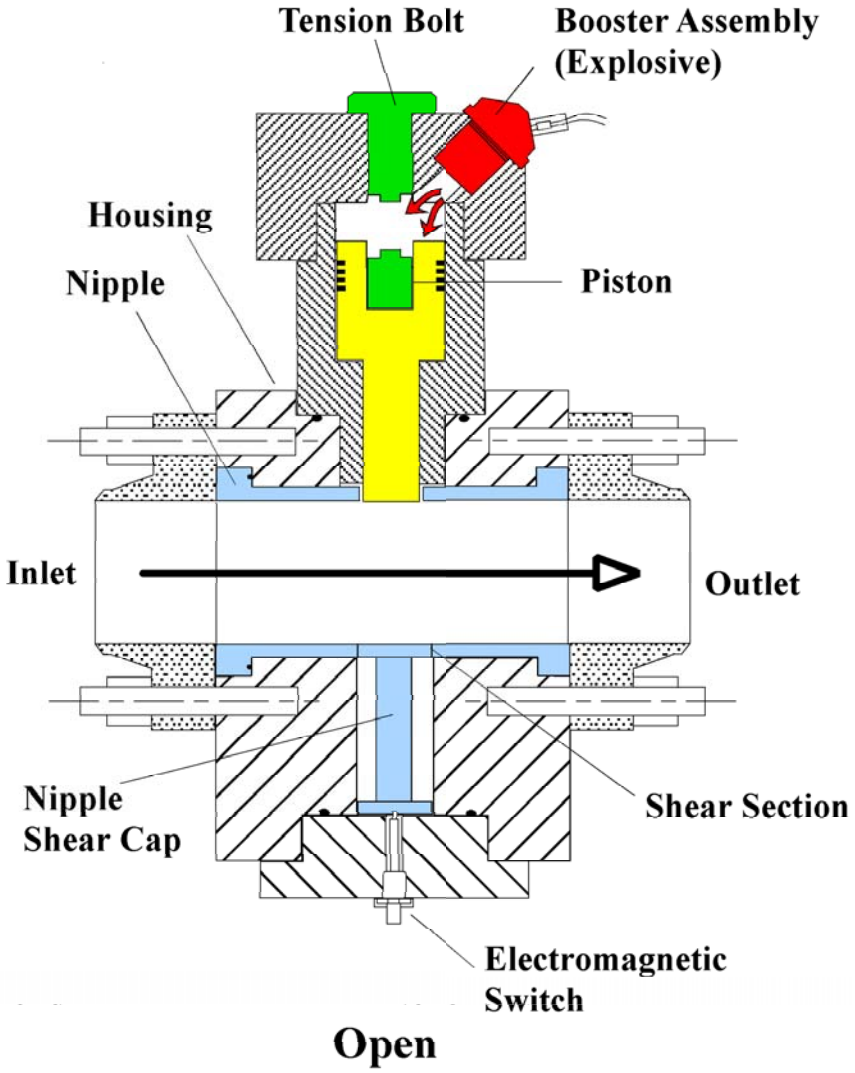

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Other Safety-Related Passive Systems

- DC Power Supplies
  - > Battery banks
  - > Inverters
  - > Battery Chargers
- Emergency Breathing Air System
  - > Main Control Room Habitability
- Standby Liquid Control (SLC)
  - > Two Pressurized Tanks of Boron

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Safety-Related Electrical

- Four Divisions
- DC Backed
  - > Inverted power for AC loads
  - > 4 Divisions with 24 hours Capability
    - – Monitor
    - – Control
  - > 2 divisions with 72 hours Capability
    - – Monitor

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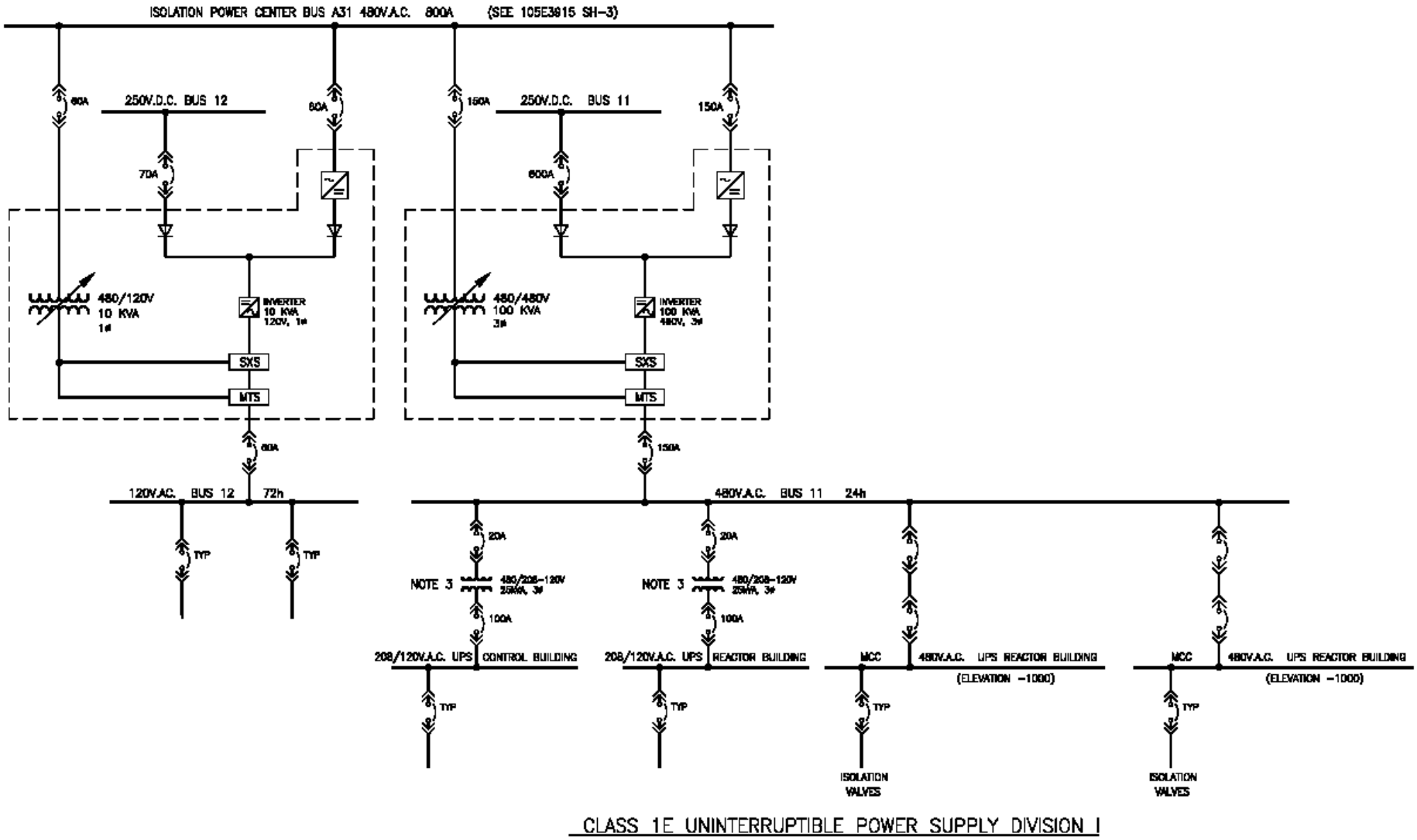
1E Electrical Arrangement



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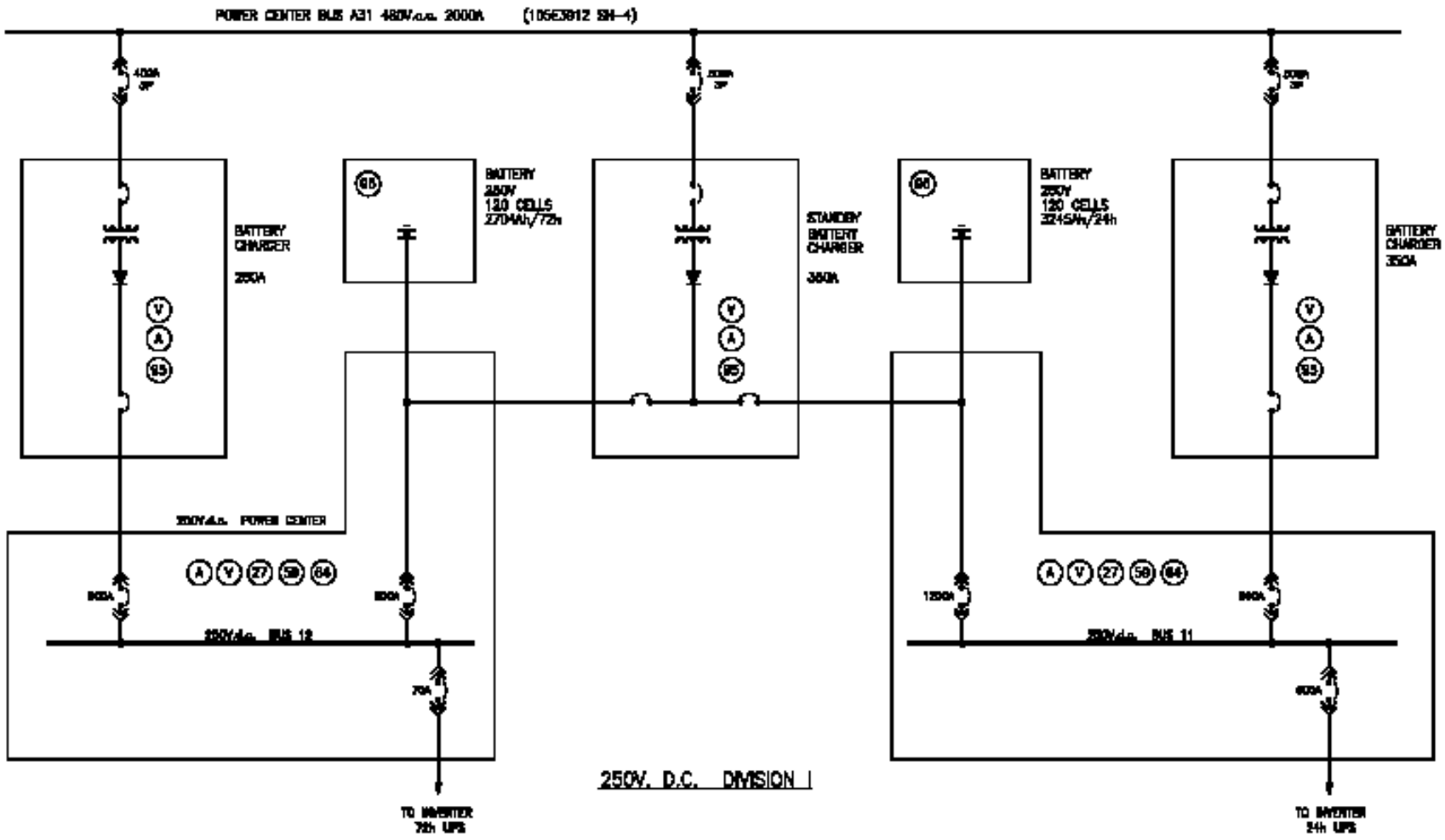
1E Electrical Arrangement (cont)



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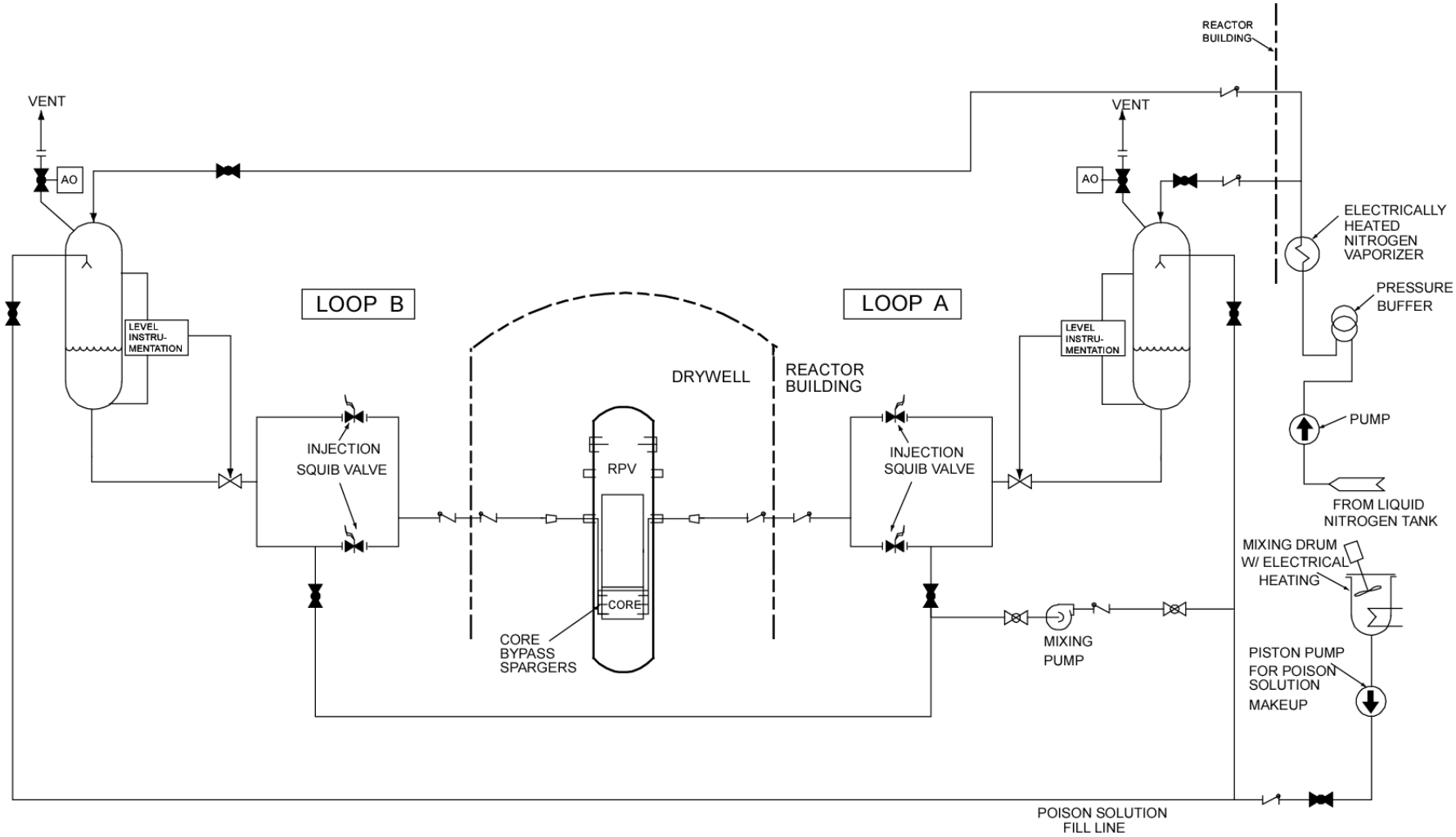
Standby Liquid Control



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Emergency Breathing Air System

- Main Control Room Habitability
  - > Pressurized space 1/8 inch water gauge
  - > EBAS safety-related
    - – Single Failure Proof
    - – 72 hour passive capability
  - > MCR HVAC non-safety related
    - – With AC power availble
    - – 2 x 100% trains
    - – HEPA and Charcoal filtration

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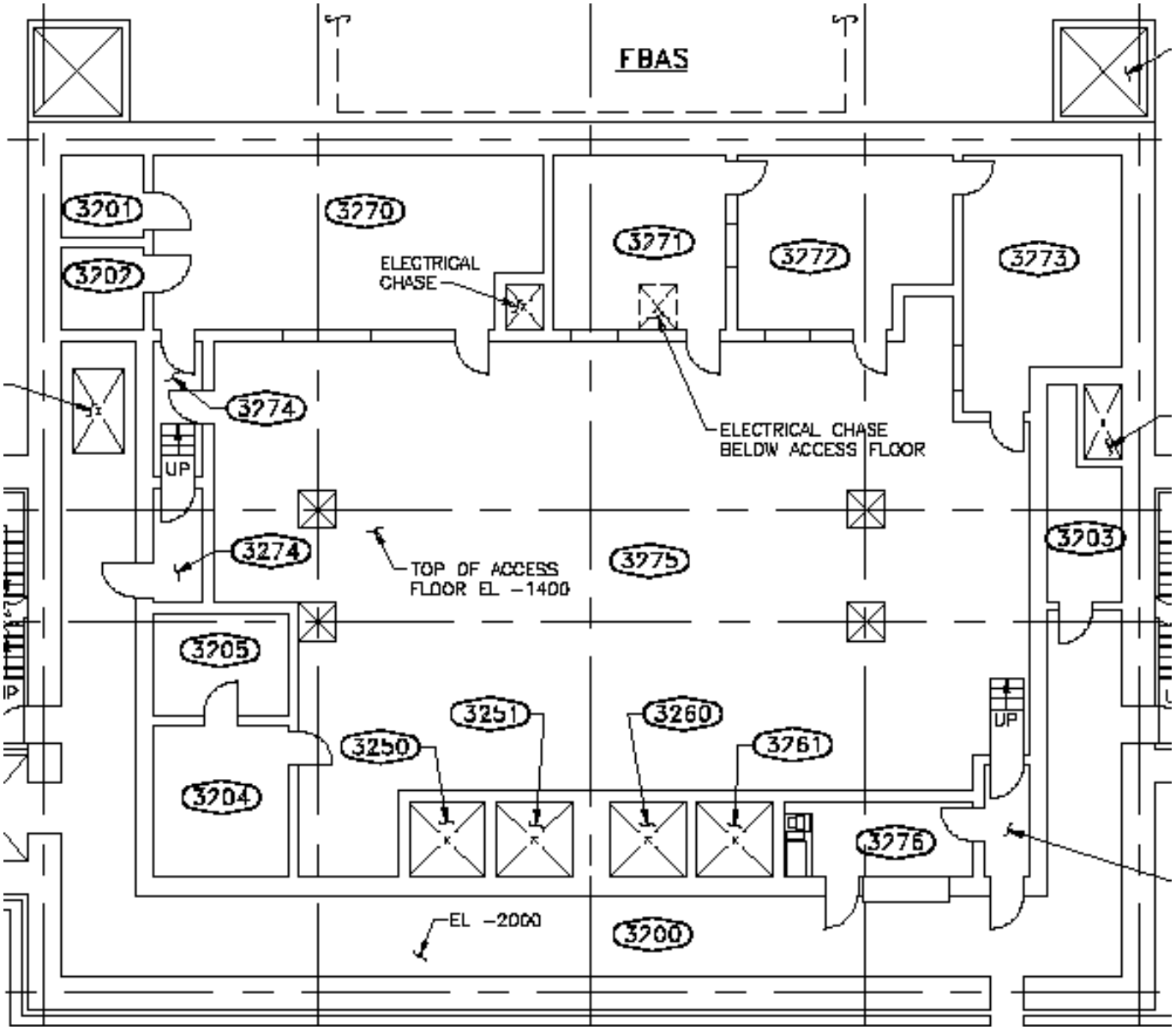

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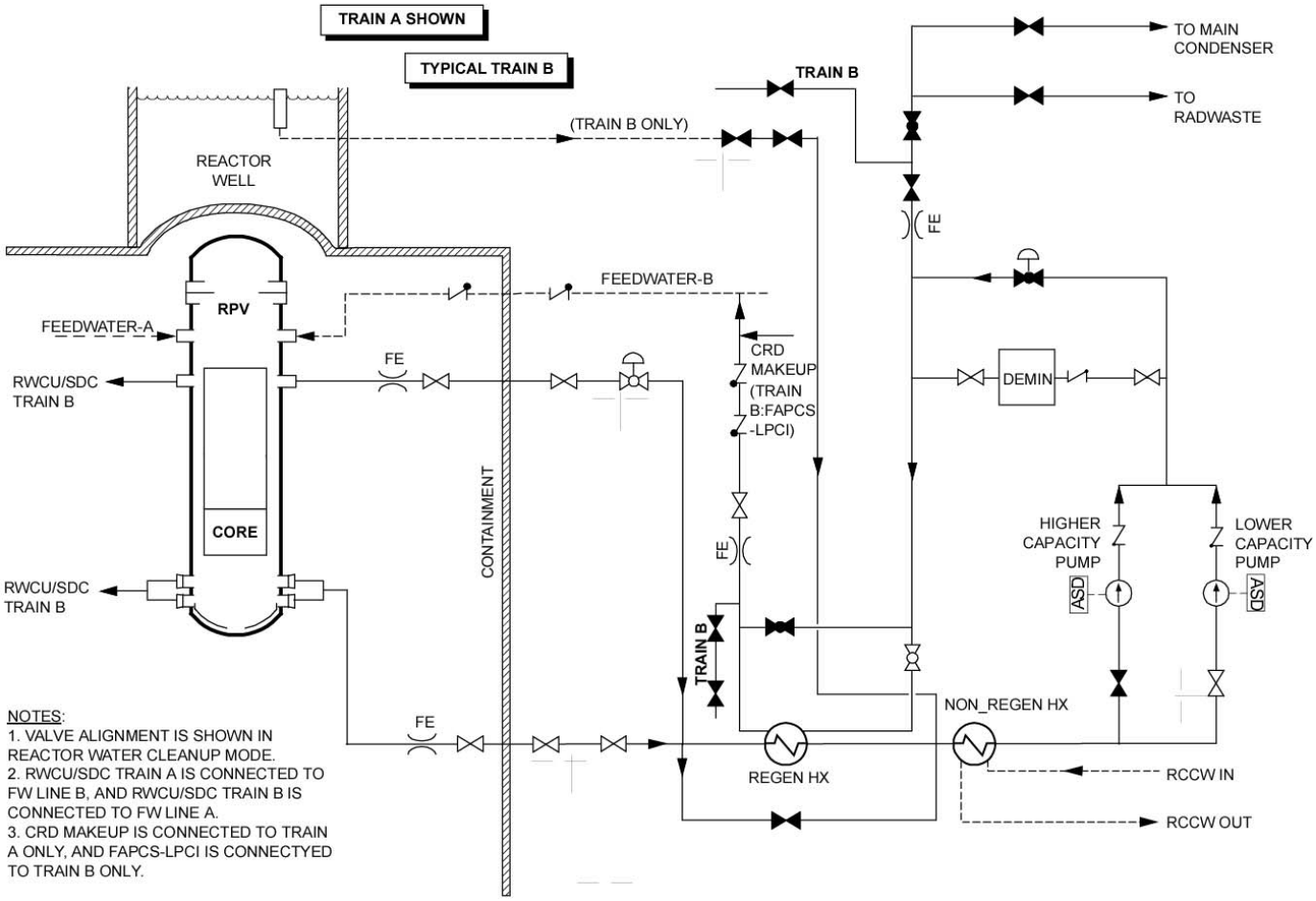
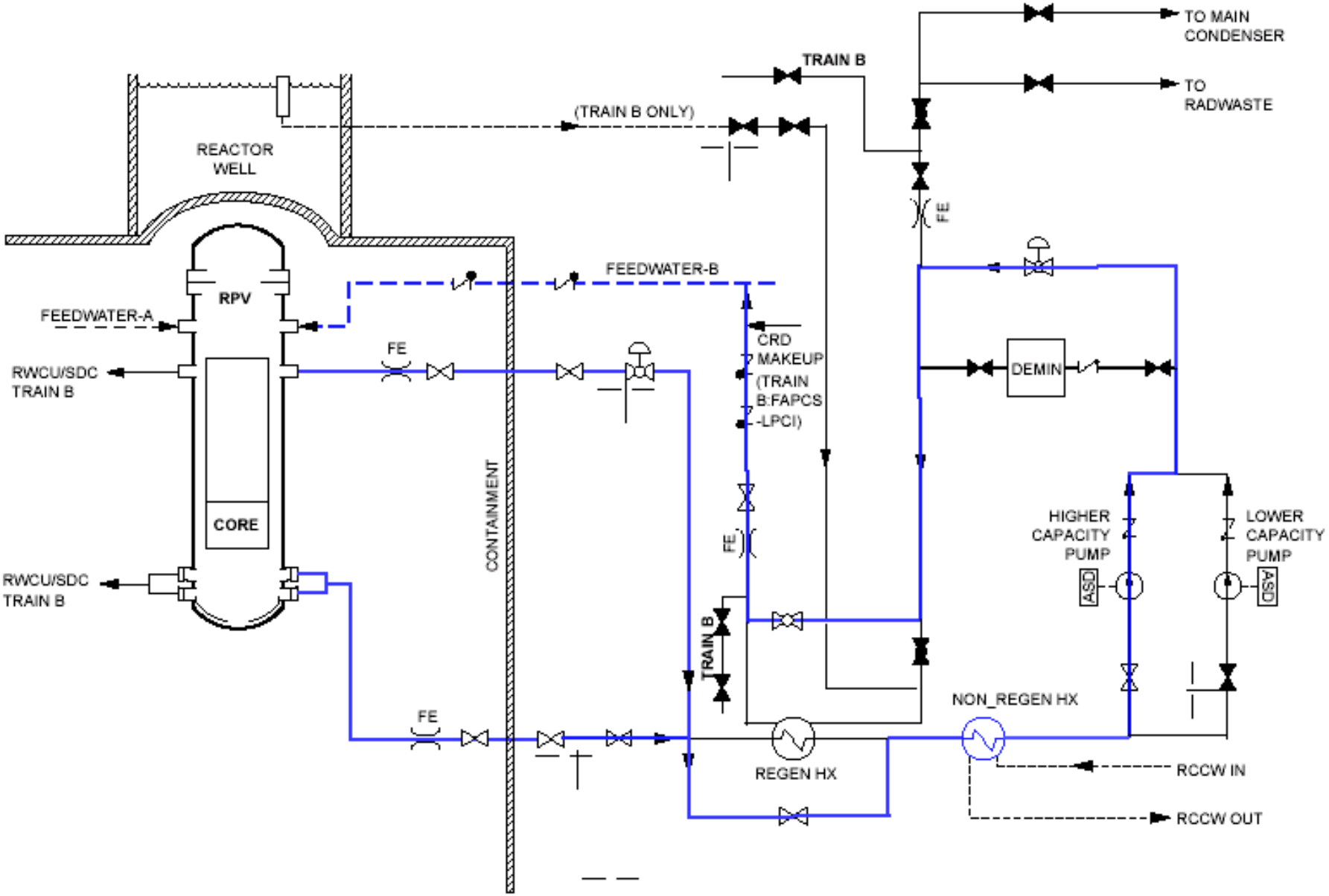
Reactor Water Cleanup (RWCU)





Shutdown Cooling

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Fine Motion Control Rod Drives (FMCRD)

- 269 Control Rods
- Hydraulic Scram
  - > 1 HCU for 2 FMCRDs
  - > FMCRDs for 1 HCU are separated in core
  - > No Scram Discharge Volume
  - > Rapid Insertion
    - – ~1.1 seconds full out to full in
  - > Reduced maintenance
- Shoot-out Steel is eliminated

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FMCRD (cont)

- Insertion and Withdrawl by Electric Motor
  - > No overshoot
  - > Can be ganged in groups as large as 26
  - > Positioning Increments of ~3 inches
  - > Rod Control and Information System (RCIS)
- Rod Drop Accident is no longer Credible
  - > Detection of blade failure to follow drive
  - > Check of blade to drive coupling integrity

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FMCRD (cont)

- Power adjustments are made with rod movement
  - > Select Control Rod Rapid Insertion (SCRRI), provides a means for rapid power reduction
- Maintenance
  - > Hydraulic portions surveillance primarily
  - > Electrical requires no break of pressure boundary

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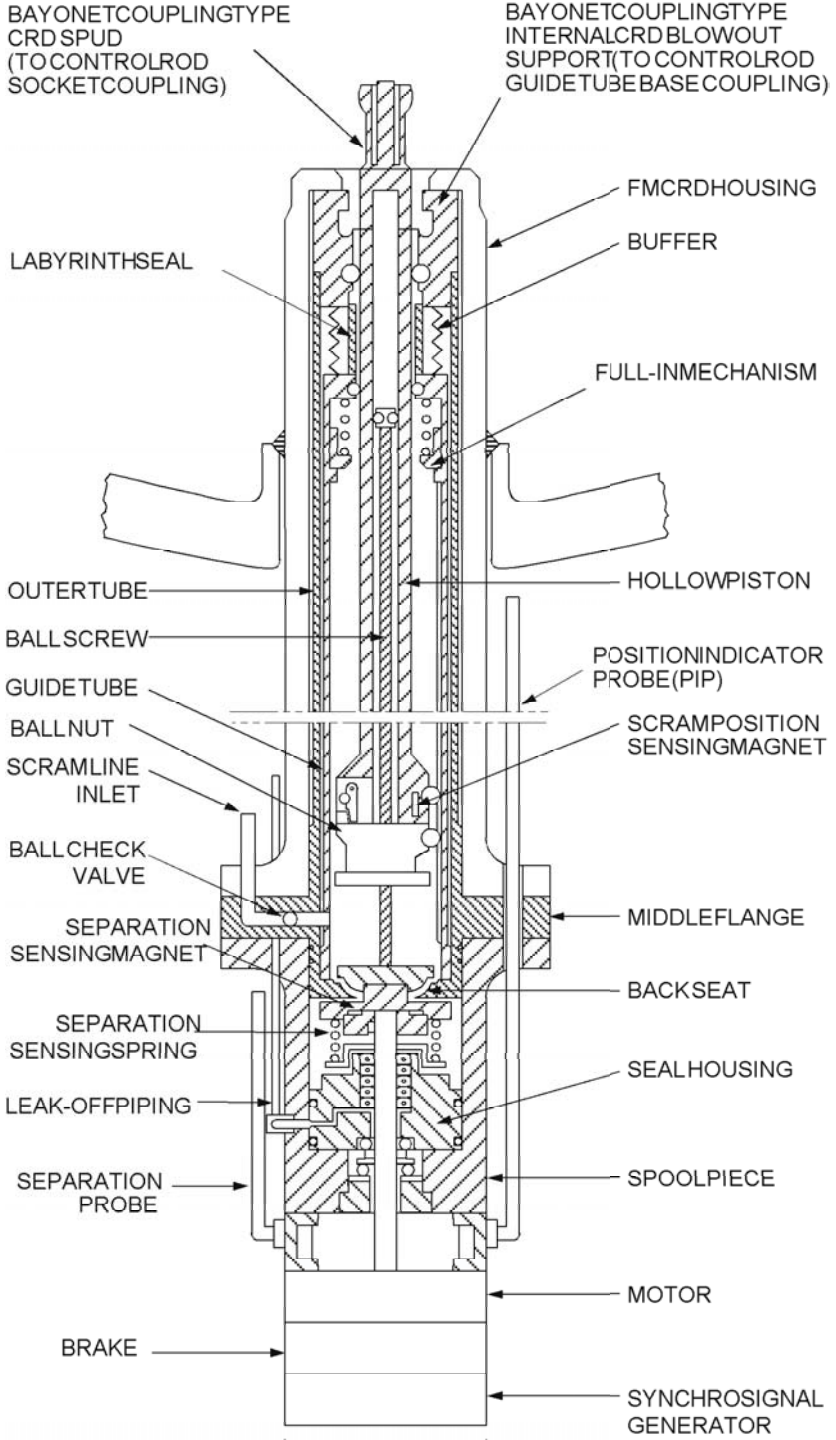
BAYONETCOUPLINGTYPE
CRD SPUD
(TO CONTROLROD
SOCKETCOUPLING)
BAYONETCOUPLINGTYPE
INTERNALCRD BLOWOUT
SUPPORT(TO CONTROLROD
GUIDETUBE BASE COUPLING)
FMCRDHOUSING
BUFFER
LABYRINTHSEAL
FULL-INMECHANISM
OUTERTUBE
HOLLOWPISTON
BALLSCREW
POSITIONINDICATOR
PROBE(PIP)
GUIDETUBE
BALLNUT
SCRAMPOSITION
SENSINGMAGNET
SCRAMLINE
INLET
BALLCHECK
VALVE
MIDDLEFLANGE
SEPARATION
SENSINGMAGNET
BACKSEAT
SEPARATION
SENSINGSPRING
SEALHOUSING
LEAK-OFFPIPING
SEPARATION
PROBE
SPOOLPIECE
MOTOR
BRAKE
SYNCHROSIGNAL
GENERATOR